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#### 5th Southeast Section Symposium 23-24 February 2012 Ramada Plaza Beach Resort

Ft. Walton Beach, FL

## 27th East Coast Symposium 13 April 2012

NAS Patuxent River, MD

# Great Lakes Section Symposium 17 May 2012

Wright-Patterson AFB - Banquet Center Dayton, Ohio

# **5th Central Section Symposium** 1 June 2012

Southwest Symposium TBD

### 55th Symposium & Banquet

26-29 September 2011 Grand Californian Hotel & Spa Anaheim, CA

# **42nd San Diego Symposium** 23-24 March 2012

Catamaran Resort Hotel & Spa San Diego, CA

# Flight Test Safety Workshop

30 April - 3 May 2012 The Renaissance Seattle Hotel Seattle, WA

# **44th European Symposium** 23-27 May 2012

Kempinski Bristol Hotel Berlin, Germany

# 2nd Northwest Symposium

12 July 2012

Future of Flight Facility, Everett, WA

#### 5th European Flight Test Safety Workshop

TBD Sweden

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Statements and opinions advanced in technical papers and letters-to-the-editor are those of the authors and do not necessarily coincide with the tenets of The Society of Experimental Test Pilots. Letters to-the-editor are encouraged whenever there are dissenting opinions.

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Cover Photo

National Test Pilot School is celebrating it's 30th Anniversary. **Photo courtesy of National Test Pilot School** 

# PRESIDENT'S MEMO



Steve Rainey (AF)
The Boeing Company
SETP President

I'm very excited about the upcoming year in SETP. I want you all to know that I am very humbled to serve as your President and I'll do my best to continue with and enhance the spirit of the Society during my tenure as President.

I'd like to thank Billie Flynn and his Board of Directors for handing me a Society in excellent condition. We are 2400 members strong and had eleven symposia this past year. I was fortunate enough to attend most of these and I can assure you that the quality and quantity of technical papers is at an all time high. I hope to continue this trend.

We are well on the way to a great year of symposia. I recently attended the SW Section Symposium and the historical theme was superior. I have always believed that a good look backwards helps you take the correct step forward. The presentations helped to focus lessons learned from history and how they apply today.

I then attended the European Flight Test Safety Workshop in Salzburg. The focus was on airshow demonstrations and preventing accidents. The product of this workshop will be a guide and checklist for airshow demonstrations - this directly supports our primary goal to increase flight test safety.

I have several initiatives that I'd like to announce.

- 1) In the Golden Era of test pilots it was a normal occurrence for Jack Northrop to drive to Edwards AFB to talk directly to the test pilots who had flown his product. Kelly Johnson's interactions with test pilots are well documented. In many cases today's program managers and CEOs are less likely to have had a background in engineering or flight test. As a result, the recognition of the value that test pilots bring to programs may have perhaps dwindled somewhat in recent years. We have established a "Marketing Test Pilot Value Committee" to address this issue. Past SETP President Doug Shane has agreed to Chair this committee. We will no doubt hear great things from this committee over the coming year.
- While our website is much better than it ever has been, I'd like to make some changes that will make it a significantly more useful tool for test pilots. As an example, the ability to search based on the type of project that you are currently working. The search would not only generate papers found on the topic but the names of test pilots with test experience in the area of interest. Currently a search is very limited. The new search would in fact search entire documents as well as the member database. In addition, SETPedia will finally get off the ground floor. It will start with the SETP Handbook and allow for an ever evolving Handbook with the ability for members to add new information. Processes, standard operating procedures, and office tasks could be automated to be more efficient. Mark Dickerson has agreed to Chair the new "IT Committee." We expect great things and I'm quite sure all of you will eventually reap the benefits of this investment.
- 3) This year the membership voted and the question about UAV operators becoming SETP members was put to rest. However, I believe that it is our responsibility as a professional group of test pilots to ensure that the same rigor that we bring to flight test of manned aircraft be applied to any aircraft being flown in national airspace. Rogers Smith has agreed to chair our new "UAV Development and Flight Test Committee." We'll

develop an official Society position on the topic and prepare appropriate presentations for anyone seeking the opinion of professional test pilots.

4) John Fergione, SETP Foundation Chairman and several SETP wives generated the SETP Partner's Family Handbook that is simply a superior product. A heartfelt thanks to Ferg for his leadership on this. In the coming year we want to expand this effort to include taking care of the family in the event of a tragedy. In Europe the Mayday Foundation fulfills this function. Lisa Brown has volunteered to be our point of contact with the Mayday Foundation and help the Board of Directors determine the direction the Society should take to ensure our families are taken care of if tragedy strikes. More to follow on this topic as the year progresses.

So as we proceed into the next year I intend to ensure that we continue to do what we do best - provide superior papers, Symposia, and fellowship to increase flight test safety. I am certain that our new initiatives and committees will ultimately have the effect of increasing efficiency for all test pilots and ultimately improving flight test safety.

I wish you all fair skies for the coming year.

Sincerely,

Steve Rainey

Steve M. Claims

# Editor's Memo: A Little Help Please!

Greetings SETP Members and associates. I'm AL Peterson, the SETP Publications Chairman and I have a favor to ask of all of you. I need your help in finding, soliciting, and sending in good technical articles, RefleXtions style articles, photos, and general member news for publication in Cockpit. Our Society members are doing great and fantastic work out there in the world, but you would never know it based on the lack of technical articles and other information that get submitted to Cockpit for consideration for publication. Quite honestly, we struggle every issue to find good technical and RefleXtions articles to publish, and I know we don't receive a fraction of the news about the great things our members are doing. If you know someone who has written a technical or historical flight test article please encourage them to submit it. If you know someone who has done some interesting flight test work (past or present) but hasn't written an article, encourage them to hit the keyboard and then send it in. Likewise for sending in news about the great things our members are doing, if you know something interesting that has happened in the flight test world please send it in. Good quality and interesting photos should also be sent in for inclusion in the news section and also for consideration for the cover of Cockpit. Cockpit is sent to and belongs to everyone in the Society and in order to keep it useful and relevant technically, journalistically, and socially we need everyone to actively seek out and send in articles, news, and photos. Thanks in advance for your support. Cheers, AL

# **TECHNICAL ARTICLES**

# FLIGHT TEST FOR H-V DIAGRAM DE-TERMINATION OF A TH-500 HELICOP-TER EQUIPPED WITH NEW MAIN ROTOR BLADES.

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Abstract: A flight test program was executed for the military qualification of a new main rotor blade model for the TH-500 helicopter employed in the Italian Air Force. Within the test program, part of the test flights were aimed to gather the required data to determine the height-velocity diagram in a clean configuration of the helicopter. In this frame, several actions were implemented in order to allow for test flight time/costs saving and for safety improvements. In particular, the explored H-V diagram was based on both analytic and off-line simulation predicted curves; moreover, a flight test technique was used where full autorotations were executed only for the most critical test points on the border of the predicted envelope. The test results obtained were used to define new helicopter limitations and normal and emergency procedures to be included in the rotorcraft flight manual. This paper discusses, among all things, how the pilot workload was one of the driving factors considered by the evaluating crew in order to clear the new H-V envelope in a safe and reliable manner.

## 1 LIST OF SIMBOLS

$C_{I}$	Lift Coefficient
$h_{cr}^{L}$	Critical height
$h_{hi}$	High hover height
$h_{lo}^{m}$	Low hover height
H-V	Height-Velocity
IGE	In Ground Effect
TC 4	T 1 C. 1

ISA International Standard Atmosphere

 $\begin{array}{lll} \text{MDHI} & \text{MD Helicopter Inc.} \\ \text{NR} & \text{Main Rotor Speed} \\ n & \text{Rotor speed ratio} = \Omega/\text{W}_{\text{s}} \\ \text{OGE} & \text{Out of Ground Effect} \\ P_{ref} & \text{Referred Power required} \end{array}$ 

 $\begin{array}{lll} P_{ref} & & \text{Referred Power re} \\ V_{cr} & & \text{Critical Velocity} \\ V_{ref} & & \text{Referred Airspeed} \\ W_{max} & & \text{Maximum Weight} \\ W_{ref} & & \text{Referred Weight} \\ W_{test} & & \text{Test Weight} \\ \end{array}$ 

 $\alpha$  low hover height scaling factor  $\beta$  high hover height scaling factor  $\gamma$  critical velocity scaling factor  $\delta$  critical height scaling factor  $\lambda$  Air density ratio =  $\rho/r_0$ Pitch attitude  $\rho$  Air Density

Air Density at sea level ISA

 $\sigma$  Solidity Ratio  $\Omega$  Rotor speed

 $\Omega$  Standard Rotor speed

## 2 INTRODUCTION

This paper presents the methodology used for the assessment and military qualification of the height-velocity (H-V) diagram of the TH-500 helicopter equipped with a new main rotor blades. The TH-500 helicopter is a single engine, five bladed, fully articulated rotor, light helicopter based on the well known McDonnell Douglas Helicopter Inc. (MDHI) MD 500E model. The helicopter is currently in service in the Italian Air Force as a basic trainer and light utility aircraft.

In the frame of the continued airworthiness activities of the helicopter, a flight test program was executed for a military qualification of a new main rotor blade model, which resulted to be the only available for acquisition by the Italian Air Force, since the old one was no longer available from the production line.

The new blades have the same external shape as the old ones, however they present significant differences in construction processes and materials used that are summarized in the following table.

Table 1

Element	Old Blades	New Blades
Abrasion strip	chord 64.9 mm material: electroformed Nichel	chord 22.4 mm material: Break formed 301 stainless steel
Root fitting assembly	material: forged Aluminum	Material: machined Titanium
Ribs	18 ribs	Single piece of aluminum honeycomb

Flight testing demonstrated that helicopter performance with new blades were significantly different than with the old blades in any flight condition. Figure 1 and Figure 2 show the referred hover and level flight performance of the helicopter equipped with both new and old blades, as determined by flight testing. Specifically, Figure 1 shows the referred power required

$$(P_{ref} = \frac{P}{\lambda n^3})$$
 versus referred weight  $(W_{ref} = \frac{W}{\lambda n^2})$  in OGE hover, while Figure 2 shows the level flight power required  $P_{ref}$  for level flight versus referred airspeed  $(V_{ref})$  for level flight at a given referred weight  $(W_{ref})$  of 1265 kg. In both figures, the referred power required curves resulted by the pre-existing RFM's data are also shown as black lines.

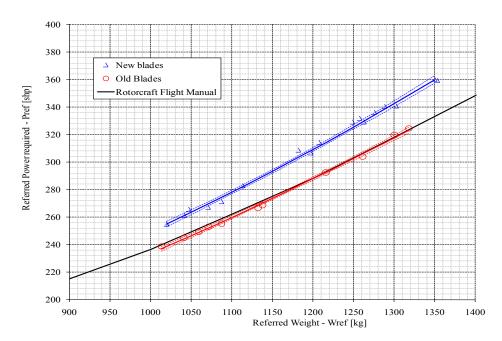


Figure 1: Referred OGE Hover Performance

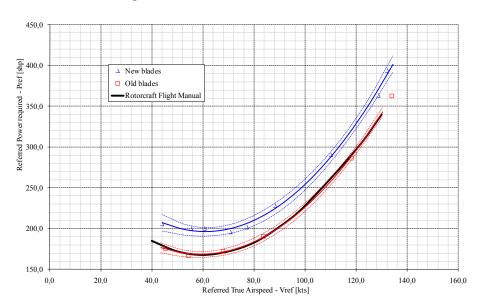


Figure 2: Referred Level Flight Performance at  $W_{ref} = 1265 \text{ kg}$ 

As figures show, the power required in any flight condition is consistently higher for the new blades. Therefore, among all, an extensive part of the flight test program was dedicated to the determination and qualification of the H-V diagram of the helicopter as equipped with this new blades. However, in order to save cost and time, and to improve the flight safety during H-V test flights, these were preceded by an analytic prediction of the H-V diagram.

## 3 ANALYTIC PREDICTION OF THE H-V DIAGRAM

The analytic prediction of the H-V diagram was conducted by means of the semi-empirical method provided by *Pegg* (Ref. [1]). This method was developed for calculation of the low speed part of H-V diagram for civilian helicopters. Although the flight test program was aimed to a military qualification, this method was judged suitable for the objective. The *Pegg*'s method uses a generalized, non-dimensional H-V diagram generated from flight test data using single-engine, single-rotor helicopters, shown in Figure 3.

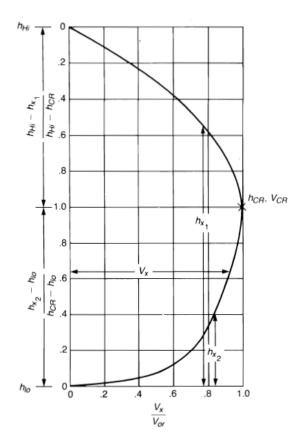


Figure 3: Generalized nondimensional H-V diagram (source Ref. [1])

The H-V diagram is identified by 4 principal parameters, listed below: 10 July - December 2011

- The critical velocity  $(V_{cr})$ , which identifies the maximum speed of the avoid area (knee point);
- The critical height  $(h_{cr})$ , which identifies the knee point height;
- The low hover height  $(h_{ij})$ , which identifies the minimum hover height of the avoid area;
- The high hover height  $(h_{hi})$ , which identifies the maximum hover height of the avoid area.

In the generalized, non-dimensional diagram, all heights are normalized with respect to the critical height  $(h_{cr})$ , while all velocities are normalized to the critical velocity  $(V_{cr})$ ; the low hover height  $(h_{lo})$  and the high hover height  $(h_{hi})$  are fixed as the zero points for the heights respectively below and above the critical height.

The characterization of the actual diagram was completed by first calculating all four parameters above  $(h_{ci}, V_{ci}, h_{lo}, h_{hi})$  in accordance to the procedure described in Ref. [1], and then un-referring the entire curve to this parameters. Calculation was made for the maximum rotorcraft weight (1361 kg) at sea level ISA, which was the qualification objective.

The following table shows the results yielded by the above calculation for both new and old blades configuration, while in Figure 4 the resulting H-V diagrams are depicted together with the existing RFM one.

Table 2

O 1 d N W Blades Blades

 $h_{cr}$  [ft] 95 95 125  $V_{cr}$  [kts] 48 43 48  $h_{lo}$  [ft] 13,8 15 12,5  $h_{i,i}$  [ft] 584 500 531

As Figure 4 shows, the shape of the H-V diagrams yielded by the *Pegg*'s method for both new and old blades is substantially different from the one published on the existing RFM. Therefore, the calculation was revised in order to propose a new diagram which approached better the RFM philosophy. Specifically, the new diagram was found by scaling three of the four principal parameters RFM diagram with multiplying factors obtained by the ratio between the *Pegg*'s parameters for the new and old blades configuration, as detailed below.

**RFM** 

$$\boldsymbol{h}_{lo_1} = \alpha \cdot \boldsymbol{h}_{lo\,RFM} \quad \boldsymbol{h}_{hi_1} = \beta \cdot \boldsymbol{h}_{hi\,RFM} \qquad \boldsymbol{V}_{cr_1} = \gamma \cdot \boldsymbol{V}_{cr\,RFM} \qquad \boldsymbol{h}_{cr_1} = \delta \cdot \boldsymbol{h}_{cr\,RFM}$$

Where:

$$\alpha = \frac{\textbf{h}_{lo\;new}}{\textbf{h}_{lo\;old}} \hspace{0.5cm} \beta = \frac{\textbf{h}_{\textbf{h}i\;new}}{\textbf{h}_{\textbf{h}i\;old}} \hspace{0.5cm} \gamma = \frac{V_{cr\;new}}{V_{cr\;old}} \hspace{0.5cm} \delta = \frac{\textbf{h}_{cr\;new}}{\textbf{h}_{cr\;old}}$$

It is worthy to notice that the factor  $\delta$  is equal to 1, which returns an unchanged critical height in the new predicted diagram.

The Pegg's method does not contain any information for prediction of the high speed – low height part of the diagram. Therefore, this part of the diagram was obtained by imposing a linearly increase from 40 kt / 0 ft to 58 kt / 30 ft; then the altitude remains constant to 30 ft for higher speeds.

Figure 5 shows the proposed H-V diagram as compared to the RFM diagram for the old blades.

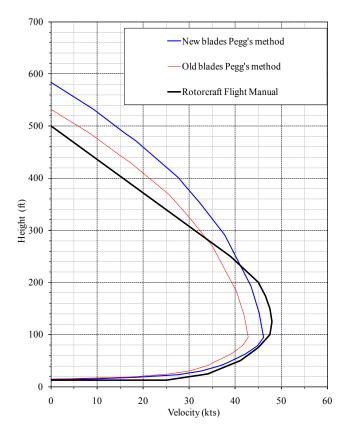


Figure 4: H-V diagram - Analytic prediction using Pegg's method compared to RFM

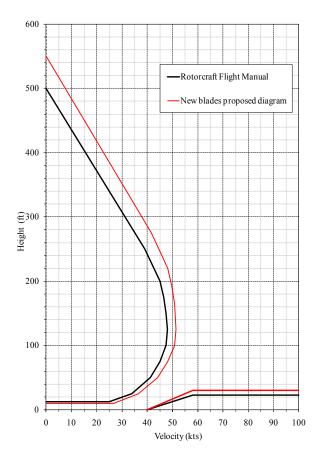


Figure 5: New blades proposed H-V diagram as compared to the RFM

The new proposed diagram was then submitted to flight testing for validation up to the maximum weight (W<sub>max</sub>) of 1361 kg at sea level ISA. All flight tests were executed in accordance to the test methodology explained in the following paragraphs. However, the first test points performed at a test weight (W<sub>test</sub>) of 1150 kg at sea level showed immediately that the low speed portion at high heights of the proposed diagram was not safe for autorotation landings at weights in excess of 1150 Kg, due to an unacceptable residual margin of energy left available during the flare and round out phases. It was clear to the flight test crew that an order of scale error of about 150 to 200 ft was present in the calculated diagram high hover height. Therefore, the calculation had to be revised in order to find a new diagram to be validated by means of flight testing.

The final diagram was created by scaling all four main parameters of the

initial proposed diagram in Figure 5 by factors that were chosen following the logic and the formulas of the *Pegg*'s method. Specifically:

- The  $h_{lo}$ , as all other parameters are maintained constant, results to be proportional to the power required in IGE hover; therefore, it was scaled by the factor  $a_1$ , yielded by the following equation:

$$\alpha_{1} = \frac{P_{IGE \ at \ W_{test}}}{P_{IGE \ at \ W_{max}}} = \left(\frac{W_{test}}{W_{max}}\right)^{\frac{3}{2}} = \left(\frac{1150}{1361}\right)^{\frac{3}{2}} = 0,7767$$

The  $V_{cr}$  is proportional to  $C_L/\sigma$ , which turns out to be directly dependent from the helicopter weight; therefore, the  $V_{cr}$  was scaled by the factor  $g_1$ , yielded by the following equation

$$\gamma_{1} = \frac{\left(\frac{C_{L}}{\sigma}\right)_{W_{\text{max}}}}{\left(\frac{C_{L}}{\sigma}\right)_{W_{\text{test}}}} = 1.183$$

- The  $h_{hi}$  is proportional to the and therefore was scaled by the factor  $b_1$ , yielded by the following equation:

$$\beta_1 = \gamma_1^2 = 1,183^2 = 1,400$$

No change were made to the high speed portion of the diagram. Figure 6 shows the final analytically predicted diagram (blue line) yielded by the above calculation. The scaling expansion of the H-V diagram, however, had as a consequence the restriction of the take-off and landing corridor, which, in accordance to the civilian certification requirements should be in excess of 10 kts at any height. In order to have a sufficient safe margin with respect to both the low speed and the high speed portions of the diagram, the shape of the calculated diagram was further revised, especially in the portion below the "knee". The final proposed diagram is depicted in black solid line.

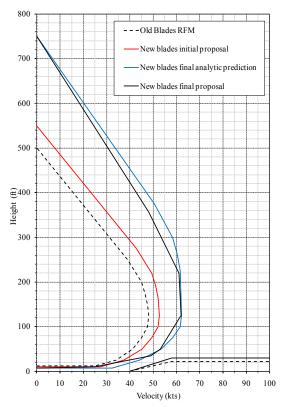


Figure 6: Final analytic prediction and proposed H-V diagrams

### 3.1 OFF-LINE SIMULATION

An off-line simulation was carried out by AgustaWestland which was the final responsible as Design Authority of the implementation of the new blade configuration; the simulation was performed thanks to the data already gathered by the flight crew during a previous performance campaign aimed at the determination of straight and level and climb/ descent performance. Thanks to the previous exploration of the performance behaviour of the main rotor equipped with the new blades, the simulation was able to verify that the final analytical prediction of the H-V diagram was sound and safe enough in order to re-start, and possibly complete, the flight test activity and the determination of the H-V diagram.

### 4 FLIGHT TEST OF THE FINAL PROPOSED H-V DIAGRAM

Both the initial and final proposals of the H-V diagram were flight tested for validation and qualification of the new configuration. The test weight was increased from 1050 kg to the maximum weight or the weight at which the diagram was judged safe, whichever came first. Since a military qualification was required and without taking into account the FAR/CS requirements, flight tests were executed only at sea level conditions, accepting the result that the validity of the diagram at any altitude up to the maximum take off and landing altitude (7000 ft for the model under evaluation) was limited to the maximum referred weight realized during the tests. A total of 8 flights were needed for flight test completion.

During each flight, the referred weight  $(W_{ref})$  was maintained constant within a range of +3/-1% by means of adding ballast as fuel was consumed and while ambient temperature and pressure changed during test execution. Tests were executed in wind conditions not in excess of 3 kts.

Within each flight, test conditions were flown with a build up approach, from the most benign condition while approaching gradually the H-V diagram border. Specifically, from a test point to the following one, only one parameter at a time among speed and altitude was changed. Figure 7 shows the entire test points sequence, where each test point is indicated by progressive numbers.

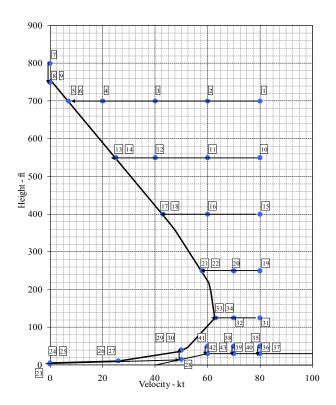


Figure 7: H-V diagram test conditions

# 4.1 FLIGHT TEST TECHNIQUE

The test consisted in performing autorotation landings with a simulation of total power loss starting from a stabilized initial test condition as reported in Figure 7, and by using a specifically prepared grass strip. In accordance to the Flight Test Manual at reference [2], the engine failure was simulated by placing engine throttle from FLIGHT to IDLE with the quickest movement possible (less than 0.5 seconds). The time of reaction for the pilot to start the intervention on the control was calculated from the moment the throttle reached the idle position to the first pilot intervention on either flight control. A 1 second time delay for pilot intervention was used for all points above the knee of the H-V diagram and a normal pilot reaction time (i.e., immediate intervention) for all points below the knee.

As it can be noted in Figure 7, test points on the border of the diagram were

executed twice. This is due to a specific test technique adopted in order to improve flight test safety and to increase the test aircraft survivability during test activity.

The rationale behind this test technique could be found in some considerations raised during the initial phase of the campaign, when the initial proposed diagram was evaluated. Specifically, it was noted that the most difficult and dangerous part of the test manoeuvre was the final touchdown and running landing phase where, regardless of the test condition acceptability for the qualification of the diagram and the test pilot skills in executing the manoeuvre, there were several factors that could have endangered the safety of the helicopter and its crew. These factors include, but are not limited to, those listed below:

- terrain conditions (wet grass usually decreases quickly the landing run due to a higher friction and to a deeper sinking of the skid into the terrain);
- terrain irregularity and roughness;
- landing skid anomalous and/or asymmetrical reaction due to unintentional different calibration of the landing skid shock absorbers;
- asymmetrical touchdown.

For this specific case, the overall risk level associated to this test phase was also increased by the higher forward speed and sink rate at touchdown noted on any test condition.

Having well understood the above assumptions, it was also noted that the touchdown conditions were always affected by the execution technique of the flare (i.e., a flare executed too high resulted in an excessive sink rate at touchdown, on the other hand, an ineffective flare could result in an excessive forward speed at touchdown, etc.). Therefore, it was possible to observe that the acceptability of the autorotation was only related to the parameters observed from the engine failure simulation up to the flare completion, i.e., the parameters representing the total amount of energy of the helicopter; therefore, once the safe execution of the manoeuvre up to the flare was fully demonstrated with a sufficient margin of energy available, the entire autorotational landing could have been considered acceptable.

Based on the considerations above, all test points were first executed with a simulated engine chop (power reduction to idle in less than 0.5 seconds) but without completion of the final touchdown phase: once the flare

manoeuvre was completed, the engine throttle was re-opened from IDLE back to FLIGHT in approximately 2 seconds, resulting in a controlled rotor engagement, followed by a final normal touchdown or by a balked landing. Every test point on the border of the diagram was first demonstrated with the above technique, and then every point was repeated with a full autorotational landing, in order to collect all the evidence of a safe autorotation needed for the military qualification.

This test methodology resulted in an increase of test points from 31 to 42 (11 more test points) at each tested weight. However, the following objectives were achieved:

- a further safer step in the build-up approach towards the border of the diagram was added, allowing a first evaluation of the test points' energy level at the border of the diagram before executing the complete autorotational landing;
- the number of effective autorotation touchdowns performed under the most critical conditions was considerably lower, allowing a better preservation of the landing skid and a lower exposure to all the factors listed above; this helped to improve fight test safety;
- the test flight duration was shorter compared to the case where all test points could have been performed with full autorotation landings, since after completion of the test points a continued flight condition could be achieved, allowing the test crew to set up for the next test point, if considered suitable; this reduced pilot fatigue and complacency with the execution of autorotation landings, which is always a high risk factor to be taken into account during a H-V testing campaign

### 4.2 EVALUATION METHOD

The execution of the autorotation manoeuvre and the residual energy level associated at each test condition were evaluated in order to validate the proposed diagram. The evaluation was conducted by assessing both the capability to maintain the main flight parameters within specified safety ranges and the pilot workload during the execution of the manoeuvre itself. Specifically, the manoeuvre was divided in the following four phases after the engine failure simulation:

Pilot reaction:

- Stabilized descent;
- Flare;
- Touchdown

For each phase of the autorotation the following parameters were controlled to be within the range specified in Table 3.

Table 3

Phase/ Parameter	Pilot reaction	Stabilized descent	Flare	Touchdown
NR	> 85%	80% < NR < 110%	< 110%	> 60%
θ	> -40°	As required	< 25°	< 12°
Velocity	As required	65 <v<75 kias<="" td=""><td>70 KIAS</td><td>&lt; 40 kt</td></v<75>	70 KIAS	< 40 kt

In order to evaluate the pilot workload during the different types of autorotations to be expected during the H-V diagram execution, two different test pilots with extensive experience on TH-500 were employed for the activity. Every test pilot undertook a specific number of training sorties by using a TH-500 helicopter equipped with the old blades. The helicopter used for the training sorties was loaded up to the maximum allowed take-off weight by incremental steps, while taking into account the level of confidence acquired by the evaluating pilots. The possibility for the evaluating crew to train on the original main rotor blade configuration allowed for a better judgement of the overall workload required when using the main rotor equipped with the new blades, where the residual energy level available before touchdown was reduced due to the reduction in the overall performance.

The workload assessment conducted on the test item helicopter covered the following points:

- NR decay after engine failure simulation and difficulties in maintaining the NR within minimum range by using the appropriate time delay of pilot intervention on the controls;
- Flying qualities difficulties encountered during the entry phase for the descent in autorotation (right pedal migration, airspeed control and associated longitudinal cyclic displacement);
- NR and airspeed control during descent phase;

- Assessment of the flare phase: selection of appropriate entry height, longitudinal attitude variation and controllability, maximum NR control and rate of decay upon collective application, directional control problems encountered, round out controllability and quickness of execution;
- Collective displacement upon touchdown and residual energy available, NR attained at touchdown, controllability of the helicopter during ground skidding.

All test points were judged by taking into account a normal pilot capacity, with a particular thought related to the main use for which the TH-500 is employed within the Italian Air Force, i.e., the training of student pilots. Although no specific Cooper-Harper Rating Scale was used in order to classify the results obtained due to the fact that only two evaluating pilots were employed for the activity, a great amount of attention was devoted to the feasibility of the manoeuvre itself with the imposed respect of the parameters of Table 2 and to the residual energy level available. Several abused cases conditions were also taken into account, in order to verify that a sufficient margin of safety was present if any operational pilot would deviate slightly from the required parameters.

### 4.3 FLIGHT TEST RESULTS

Flight test demonstrated that the proposed H-V diagram was safe for autorotational landings up to a maximum referred weight  $W_{ref}$  of 1300 kg. At a higher weight, a further expansion of the curve in the low speed portion would have been necessary. However, a further increase of the avoid zone was deemed unfeasible, due to an unacceptable restriction of the take-off and landing corridor. As a consequence, the helicopter maximum weight was restricted at 1300 kg at sea level ISA, with linear decrease with density altitude, in order to maintain a 1300 kg constant  $W_{ref}$ 

The autorotation entry, although still safe in any condition, presented a lower NR as compared to the previous blades configuration.

Furthermore, in order to stay outside of any condition of the proposed diagram, the stabilized descent speed for autorotation previously published in the RFM was shifted from 60 KIAS to 70 KIAS, while the flare height was decreased from 150 ft to 90 ft. With these parameters, the overall maneuver translated into a more aggressive flare execution with higher maximum pitch angle, which also resulted in an increase of the maximum NR as high

as 110%, which consequently required a positive control with collective application well before the level-off and touch-down phase.

### 5 CONCLUSION

A flight test program was executed for the military qualification of a new main rotor blade model for the TH-500 helicopter. Within the test program, part of the test flights were aimed to gather the required data to determine the height-velocity diagram in a clean configuration of the helicopter. The H-V diagram was first predicted by using a tailored semi-empirical *Pegg*'s method which took into account the shape of the old blades RFM H-V diagram. The resulting diagram was judged to be unacceptable for safe autorotational landings for weights in excess of 1150 kg. Therefore the predicted H-V diagram was further modified, by up-scaling the diagram with appropriate scaling factors, chosen by following the logic and the formulas of the *Pegg*'s method. The resulting H-V diagram was also verified before flight testing with an off-line simulation program conducted by AgustaWestland.

In order to improve flight test safety and to increase the test aircraft survivability during test activity, a particular test technique was adopted. Specifically, all test points were first executed without completion of the final touchdown phase; only the test points on the border of the diagram were first demonstrated with the above technique, and then repeated with a full autorotational landing, in order to collect all the evidence of a safe autorotation needed for the military qualification. With this methodology the following objectives were achieved:

- a further safer step in the build-up approach towards the border of the diagram was added;
- the number of effective autorotation touchdowns performed under the most critical conditions was considerably lower;
- test flight duration for every flight was shorter compared to the case where all test points could have been performed with full autorotation landings by also reducing pilot fatigue and complacency with the execution of autorotation landings.

The evaluation of each test point was conducted by assessing both the capability to maintain the main flight parameters within specified safety ranges and the pilot workload during the execution of the manoeuvre itself, by employing two different test pilots with extensive experience on TH-500. 22 July - December 2011

All test points were judged by taking into account a normal pilot capacity, with a particular thought related to the main use for which the TH-500 is employed within the Italian Air Force, i.e., the training of student pilots.

#### 5.1 LESSONS LEARNT

The overall program allowed to gain the following lessons learnt that are worthy to share in the flight test community:

- Materials and construction also count. Aerodynamics and performance is not only a matter of shape. These could seem obvious for most of the specialists. However, it is worthy to notice that blades were initially presented by the blade's manufacturer as equivalent, interchangeable and mixable to the old blades. Flight Test confirmed that the helicopter with new blades had performance significantly lower than the old blades configuration. As an obvious consequence, the shape of the H-V diagram resulted to be very different, such as the expansion of the low speed portion.
- Sometimes, the most dangerous part of a flight test is not the one you need. The final touchdown with no doubt is the most endangering part of the autorotational landing, where regardless of the test condition acceptability for the qualification of the diagram and the test pilot skills in executing the manoeuvre, there are several external factors that can endanger the safety of the helicopter and its crew. Nevertheless, it was possible to observe that the acceptability of the autorotation was only related to the parameters observed from the engine failure simulation up to the flare completion; therefore, once the safe execution of the manoeuvre up to the flare was fully demonstrated with a sufficient margin of energy available, the entire autorotation landing could have been considered acceptable. This consideration allowed the introduction of the particular test technique, in which only the points on the diagram border were repeated, with much less exposure to the test manoeuvre phase with higher risks associated.
- A practical tool for analytical prediction of the H-V diagram is **necessary** for improvement of the flight test safety and for proper flight test planning and management. Single engine helicopter H-V diagram testing could be considered as the higher risk among all flight test activities. *Pegg*'s method is an excellent starting point, however, the experience showed that it was not completely reliable July - December 2011 23

- for the specific case, since tailored modifications were still necessary.
- Always thrust flight test as the "Last Word". Beyond any certification requirement, flight test was really the last and the only effective mean for H-V diagram validation, with all risk associated with this kind of tests. Is this still acceptable nowadays?

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### LIMITED EVALUATION OF AIM-9 CONTROL SURFACE EFFECTS ON F-16 LCO CHARACTERISTICS

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**Keywords:** Limit Cycle Oscillation (LCO), F-16, AIM-9

Abstract: Limit Cycle Oscillation (LCO) is a self-sustained airframe structural response due to interaction between airframe aeroelastic properties and flight condition aerodynamic effects. F-16 LCO has typically resulted in lateral motions of the fuselage and crew that could have operational impacts on such things as pilot fatigue, weapons tracking or structural integrity. Historic flight test data could not isolate the effect that aerodynamic differences had on LCO over mass and inertia differences. This test observed and compared LCO characteristics (onset, frequency and amplitude) for an F 16D with common store loadouts, varying only AIM-9 aerodynamic properties while keeping mass and inertia properties fixed. The AIM-9 missiles used for testing were capable of having all control surfaces removed, and are denoted as "dummy AIM-9s". When control surfaces were removed, ballast was added to the dummy AIM-9 bodies to match the mass and inertia properties of the dummy AIM-9s with the control surfaces attached (referred to as "fins on"). The general objective was to observe and compare F-16 LCO characteristics between store loadouts with dummy AIM-9 fins on and fins off. Of interest were minimum Mach for LCO at 1g, LCO wingtip acceleration amplitude and LCO frequency. A quantifiable difference in minimum LCO Mach number and LCO wingtip acceleration amplitude was found between fins on and fins off configurations. There was no consistent trend in minimum LCO onset between the two configurations. Fins configuration did not appear to have an effect on LCO frequency. From statistical analysis, the significant main factors affecting the LCO response were ambient static pressure, Mach, wing fuel, fins configuration and normal acceleration. The results from this testing will ultimately contribute to enhancing aircrew safety and mission effectiveness. Additionally, the data and statistical analysis will aid in updating current aerodynamic models in order to better understand, and more accurately predict, LCO.

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#### 1 INTRODUCTION

The HAVE FINS Test Management Project (TMP) was conducted as requested by the Air Force Institute of Technology (AFIT) and the Air Force SEEK EAGLE Office (AFSEO) to evaluate the effects of AIM-9 control surface aerodynamics on F-16 Limit Cycle Oscillation (LCO). The responsible test organization for this project was the 412th Test Wing. The HAVE FINS test team acted as the executing organization as directed by the Commandant of USAF Test Pilot School (TPS). Testing consisted of instrumentation ground checks and eight F-16D data sorties within the R-2508 complex of Edwards Air Force Base totaling 13.7 flight test hours. Flight testing was conducted from 7 to 20 September 2010.

#### 1.2 Background

External store aerodynamics have appreciable effects on F-16 wing aeroelastic response. The F-16 has historically experienced LCO rather than classical flutter. LCO can easily be confused with classical flutter, but they are in fact different, yet related phenomena. Unbounded flutter is a dynamic instability in which oscillations grow unbounded after initial excitation. LCO, as the name implies, involves limited amplitude oscillatory motion. This motion for the F-16 is typically characterized by anti-symmetric motion of the wing and stores and a lateral motion of the fuselage and crew. While typically not catastrophic like unbounded flutter, this phenomenon could have negative impacts on aircraft design and operation. The original F-16 flutter testing required only a single store loadout of one missile carried on each wingtip launcher. Each subsequent store loading required new certification due to the non-linear effects of LCO. The dramatic increase in stores available to the F-16, and the subsequent certification of each individual store combination prior to operational use, had developed into an extremely expensive and dangerous problem for the United States Air This problem was further compounded by store downloads and the variations resulting. These combinations turned a single configuration analysis/certification into one that also included its many permutations. The AFSEO was responsible for configuration certification, accomplishing this through a variety of means including comparison with similar store configurations, computerized analysis, and flight test. The most critical store configurations deemed flutter sensitive required flight test. With the ever increasing types of stores available to the F-16, combined with the budget sensitive environment, flight testing every needed store configuration had rapidly become a problem. Finding better and less expensive methods of flutter analysis outside of flight test was desired to reduce overall cost and time involved in a configuration flight clearance.

Historic flight test data had shown measurable differences in LCO characteristics between various configurations of the F-16; however, the relative influence of the aerodynamic effects versus the inertial effects were difficult to discern. To refine flutter software analysis methods, AFSEO desired to isolate the aerodynamic effects. The purpose of this flight test program was to determine if the control surfaces of AIM-9 type missiles affected the LCO characteristics and if so by how much. Dummy AIM-9 missile bodies with removable fins/canards and removable ballast were provided by AFSEO. Removable ballast ensured that the mass properties of the missiles remained identical regardless of configuration, and the only difference was the aerodynamic influence of the fins/canards.

#### 1.3 Test Item Description

The test aircraft was a Block 30 Lockheed Martin F-16D (tail number 87-0377), which utilized a Data Acquisition System (DAS). The LAU-129 launchers on Stations 1 and 9 were instrumented with both forward and aft accelerometers to measure vertical accelerations. The

same aircraft was used for each test flight. The aircraft was equipped with telemetry for real time assessment of wingtip accelerations. More information regarding the test aircraft can be found in reference 1. Each tested configuration included three external fuel tanks. Fuel was burned from the external centerline tank, but the external wing fuel tanks were in the "blocked" configuration, meaning no fuel was transferred from the external wing tanks to the aircraft engine. These tanks were partially loaded as Full-Empty-Full (FEF) for stores loadouts 2 and 3, SL2 and SL3, respectively. When flown with SL1, the wing tanks were completely empty, thus Empty-Empty (EEE). The three weapons store loadouts (SL1, SL2, and SL3) were symmetric and are depicted in figures 1, 2 and 3 below:

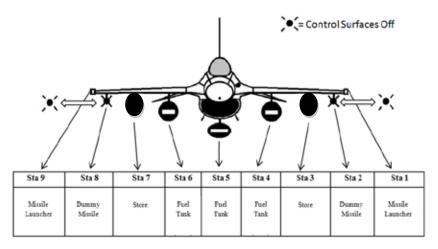


Figure 1: SL1 - Inboard Only AIM-9

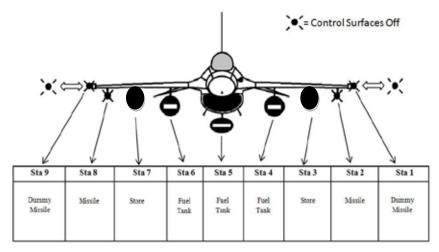


Figure 2: SL2 - Outboard and Inboard AIM-9

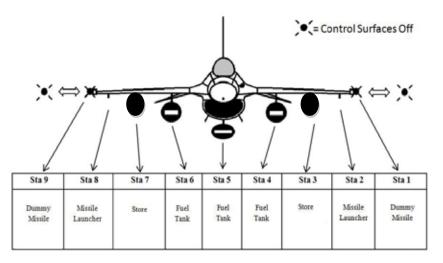


Figure 3: SL3 - Outboard Only AIM-9

The test aircraft was equipped with a Teletronics Technology Corporation DAS which was used to record the LAU-129 accelerations along with other standard data parameters (reference 2). The DAS system included a telemetry system to transmit test parameters to the USAF TPS control room for real time monitoring, evaluation, point-to-point clearance, and test point termination.

The dummy AIM-9 missiles required no power or instrumentation during flight. Instrumented LAU-129 wingtip missile launchers measured wingtip oscillations and the aircraft DAS transmitted those data to a control room real time via telemetry link.

One set of dummy AIM-9 missile bodies with removable fins/canards and changeable mass properties was provided by the AFSEO. In the fins on configuration, the dummy missiles were similar to the aerodynamic and mass and inertia properties of the AIM-9P. Using a missile shape similar to the AIM-9P reduced the risk of the flight test program, as much LCO testing had previously been conducted using AIM-9Ps. The test missile bodies were capable of conversion to a control surface-off configuration by removal of collars attached to the fins and canards. Ballast was added to the tail and nose sections upon removal of the control surfaces to ensure mass and inertia characteristics remained nearly identical. Doing this allowed the test team to isolate the aerodynamic effects of the missile control surfaces. The missile shape and ballast are shown in figures 4, 5 and 6.



Figure 4: Dummy AIM-9 Missile



Figure 5: Dummy AIM-9 Forward Ballast



Figure 6: Dummy AIM-9 Rear Ballast

## 1.4 Test Objectives

The general test objective was to observe and compare LCO for the test F-16D given three different store loadouts changing only the control surface configuration of the dummy AIM-9 missiles which were symmetrically mounted on wing stations. Specifically the minimum LCO Mach number, LCO amplitude, and LCO frequency were to be characterized and compared between the fins on and off configurations. The test objective was to provide AFSEO data that would help enhance flutter analysis methods outside of flight test, ultimately decreasing the time and cost associated with certifying new store loadouts. All test objectives were met.

#### 1.4.1 Objective 1

Observe LCO characteristics in test configurations with dummy AIM-9 fins on and fins off. The LCO characteristics consisted of the three following items:

- Minimum LCO Mach number, which was defined as the minimum Mach number at 1g at which sustained LCO could be excited.
- Wingtip acceleration amplitudes, which were defined as the Z-axis accelerations of the forward and aft LAU-129 launcher rail accelerometers. Wingtip accelerations were the fundamental data to determine LCO response because they showed the relative magnitude of LCO response and, for a given frequency, were the primary determinant for abort criteria.
- LCO frequency, which was defined as the fundamental frequency of launcher rail tip accelerations caused by LCO. Launcher rail Z-axis acceleration was analyzed through a Fast Fourier Transform (FFT) to observe frequency-domain response.

#### 1.4.2 Objective 2

Compare LCO characteristics in test configurations with dummy AIM-9 fins on and fins off. The data gathered from Objective 1 were used to compare similarities and/or differences in minimum LCO Mach number, LCO magnitude and LCO frequency between dummy AIM-9 control surface on and control surface off configurations at the different Mach and altitude bands.

#### 2 TEST AND EVALUATION

Test sorties were accomplished from 7 to 20 September 2010. Eight sorties were accomplished, totaling 13.7 hours in the F-16D. Table 1 presents sorties flown, aircrew and store loadout. Minimum LCO Mach analysis, LCO frequency analysis and LCO amplitude analysis were conducted for each store loadout between the fins on and fins off configurations. All pilots had a fighter jet background. An experienced LCO test pilot was in the test aircraft for each sortie: Maj Peter Vitt, USAF TPS, flew on all sorties except for sortie number 6; Maj Matthew Phillips, USAF TPS, flew sortie number 6.

Sortie	Date	Store Loadout	Pilot	Back-Seater
1	7 Sep	SL1 - On	Groult	Vitt
2	8 Sep	SL1 - Off	Massett	Vitt
3	9 Sep	SL2 – Off	Ungerman	Vitt
4	10 Sep	SL2 – On	Massett	Vitt
5	15 Sep	SL3 – On	Vitt	Honabarger
6	16 Sep	SL3 – Off	Phillips	Salk
7	17 Sep	SL1 – Off	Ungerman	Vitt
8	20 Sep	SL1 - On	Vitt	DePaolis

**Table 1: Completed Sorties** 

#### 2.1 Overview

Flight test maneuvers were accomplished at four different discrete altitudes. Ten thousand feet pressure altitude (PA) and 5,000 feet PA were accomplished first and considered the highest priority data since LCO typically increases for decreasing altitude and similar Mach

numbers. Data were also collected at 15,000 and 20,000 feet PA when time and fuel permitted. In each altitude band, a buildup approach from lower Mach (where no LCO response was expected) to higher Mach, where LCO was expected to occur was used. Mach was increased for each altitude until maximum planned Mach was reached or Uniform Abort Policy criteria reached in straight and level, unaccelerated flight (reference 3). Test points were flown in a similar order between sorties in an effort to keep fuel quantities and aircraft fuel distribution similar for data comparison.

#### 2.2 Minimum Mach Number

Minimum LCO Mach number was calculated by observing the time history plots and determining when the plot transitioned from noise to LCO. The power spectral density (PSD) function was also utilized to determine the frequency content of the time history plot and determine when only one peak PSD frequency was present at the predicted LCO frequency. The Mach number where LCO was first seen in the time history and PSD plots was determined to be the minimum LCO Mach number.

#### 2.3 LCO Frequency

Frequency analysis was performed using Symvionics' IADS power spectral density (PSD) for analysis. The peak PSD frequency over a 10 second time interval from stabilized LCO was recorded. Left and right wingtip accelerometers were evaluated and in all cases remained identical. LCO frequency was strongly related to store loadout.

Given the resolution of the LCO frequency, due to the algorithm used for data analysis, and given the fact that the LCO frequencies between fins configuration on and fins configuration off were always very close for similar flight conditions, fins configuration (on or off) did not appear to have an effect on LCO frequency directly by looking at the raw data. As a consequence it was also not possible to determine an absolute trend for LCO frequency when comparing fins on and fins off configurations, by only examining the raw data. However, by using statistical tools, it was possible to show that statistically fins configuration was a main factor for LCO frequency. No general trend could be proven.

In all store loadouts and fins configurations, it appeared that LCO frequency tended to increase with altitude. In all cases, LCO frequency depended strongly on store loadout and varied very less with altitude and fins configuration.

#### 2.4 LCO Amplitude Analysis

LCO amplitude was recorded at each 1g test point. Additionally, windup turns were flown at selected test points to evaluate elevated load factor effects on LCO. Load factor was increased in discrete steps until either abort levels were reached, the LCO damped out, or a 4g load factor was attained. LCO amplitude initially increased under increasing load factor and for those cases where abort amplitude was not reached in the wind up turn (WUT), eventually damped out at a higher load factor.

#### 3 STATISTICAL ANALYSIS

Design-Expert v7 was used to evaluate the statistical significance of several different independent variables on LCO frequency (modal frequency), LCO amplitude (the highest of the four wingtip accelerations), and LCO growth rate. These three measures of LCO were considered the three most relevant results, or dependent variables.

Total number of test points for each configuration (SL1, SL2, SL3) limited the ability to perform a complete main factor analysis. The test team focused on those independent variables suspected as the most influential based on historical F-16 LCO test results. The factors selected as possible significant main factors affecting the three LCO response variables were static ambient pressure, Mach, normal acceleration, fin configuration, and wing fuel. The assumptions for the LCO characteristics analysis were: 1) test points were flown at the same total weight for both fin configurations and 2) the SL configuration was a main factor and therefore it was valid to perform the analysis separately for SL1, SL2, and SL3.

A statistically significant variable was defined as one having a p-value less than 0.05. This meant there was a 95 percent confidence that the variable influenced at least one of the three dependent variables. Another way to verify the goodness of fit of the regression model and its statistical significance was to perform an F-test of the overall fit. A good model fit had an F-value greater than one and the higher the F-value, the better the fit. Simlarly, a p-value less than 0.05 indicated that the model (fit) was significant.

Surface Response analysis and the two factors interaction polynomial design model were applied to the one hundred sixty-one test points for SL3 configuration without any blocking. The modified design model investigated the significance of Mach, ambient static pressure, normal acceleration, wing fuel, fin configuration, dynamic pressure, and the Mach and normal acceleration interaction. No aliases were found for the reduced cubic model. The test power at the 5 percent significance level for all factors, except for dynamic pressure, was well above the conventional minimum required eighty percent at two standard deviations. Correlation and multi-co-linearity didn't represent an issue.

The full statistical data analysis for SL3 configuration is presented in the following sections. For SL2 configuration, the main factors analysis results were the same. This was an expected result since SL2 and SL3 fin configurations both had the dummy missiles on stations 1 and 9 and presumably experienced similar aerodynamic effects. Even though the missiles were located at different stations on the wing for SL1 (stations 2 and 8), the statistical analysis confirmed the same main factors for SL1 as for SL2 and SL3 configurations. However, the effect of fin configuration for SL1 on the response variables was different than the effect of fin configuration for SL2 and SL3.

#### 3.1 LCO Amplitude – Surface Response Analysis

The results from the ANOVA analysis for the LCO amplitude response are shown in table 2. The model F-value of 65.20 implied the model was significant and there was less than a 1 percent chance that a model F-value this large could occur due to noise. The small p-values, less than 0.05, for the ambient static pressure, Mach, fins configuration and the second-order Mach and normal acceleration interaction indicated that these variables were significant main

factors in the model. The lack of fit F-value of 0.39 implied the lack of fit was not significant relative to the pure error and there is a 98.69 percent chance that a lack of fit F-value this large could occur due to noise. Non-significant lack of fit meant that the model fit the actual data very well. The R-squared value of 0.7743, Predicted R-squared of 0.7428, Adjusted Rsquared of 0.7625, and Adequacy Precision of 36.598 confirmed that the model could be used for analysis.

Source	Sum of Squares	Degree of Freedom	Mean Square	F-value	p-value	Significance
Model	17.90	8	2.24	65.20	< 0.0001	Significant
Ambient Static Pressure	0.36	1	0.36	10.37	0.0016	Significant
Mach	12.29	1	12.29	358.16	< 0.0001	Significant
Normal Acceleration	0.062	1	0.062	1.80	0.1815	Not Signif.
Wing Fuel	0.31	2	0.16	4.58	0.0117	Significant
Fins configuration	1.81	1	1.81	52.79	<0.0001	Significant
Mach-Normal Accel interaction	0.97	1	0.97	28.22	<0.0001	Significant
Dynamic Pressure	0.041	1	0.041	1.20	0.2742	Not Signif.
Residual	5.22	152	0.034	/	/	/
Lack of Fit	4.57	144	0.032	0.39	0.9869	Not Signif.
Pure Error	0.64	8	0.080	/	/	/
Correlation Total	23.12	160	/	/	/	/

Table 2: ANOVA for Response Surface Reduced Cubic Model - Analysis of Variance Table [Classical Sum of Squares -Type III] - LCO Amplitude

The significant main factors for the LCO amplitude response resulted to be ambient static pressure, Mach, wing fuel, fin configuration, and the second-order Mach and normal acceleration interaction. This interaction was predicted during the testing phase, due to the different LCO characteristics shown by the aircraft at increased load factor for different Mach numbers. A similar result was expected also for the LCO growth rate response and it was confirmed by the ANOVA analysis. Based on the LCO amplitudes before and after air refueling, a significant wing fuel influence on LCO was predicted and confirmed by the statistical analysis. Dynamic pressure and normal acceleration were not main factors, but they were not removed from the model because normal acceleration was found to have a significant interaction with Mach.

Equation 1 represents the LCO amplitude model. In this equation the coefficients show the relative influence of different variables on LCO amplitude. The variable values have been normalized to coded factors between -1 to +1

LCO Amplitude = 
$$0.45*(Mach) - 0.28*(second-order Mach and normal acceleration interaction) +0.11*(fins configuration) +0.098*(ambient static pressure) +[-0.077 0.082]*[wing fuel1 wing fuel2]^T+(marginal factors contribution) (1)$$

Based on the relative weights of the coefficients shown in Equation 1, the contribution of Mach number to LCO amplitude was the most important, followed by the Mach and normal acceleration interaction, then fins configuration, and finally wing fuel.

#### 3.2 LCO Frequency - Surface Response Analysis

The results from the ANOVA analysis for the LCO frequency response are shown in table 3. The Model F-value of 29.77 implies the model was significant and there was less than a 1 percent chance that a model F-value this large could occur due to noise. The small p-values, less than 0.05, for the ambient static pressure, Mach, fin configuration and Mach-wing fuel interaction mean these variables were significant main factors in the model. The R-squared value of 0.6365, Predicted R-squared of 0.5762, Adjusted R-squared of 0.6152 and Adequacy Precision of 25.729 confirmed the model could be used for the analysis purposes.

Source	Sum of Squares	Degree of Freedom	Mean Square	F-value	p-value	Significance
Model	0.80	8	0.100	29.77	< 0.0001	Significant
Ambient Static Pressure	0.052	1	0.052	15.48	0.0001	Significant
Mach	0.52	1	0.52	154.84	< 0.0001	Significant
Normal Acceleration	3.305E-003	1	3.305E-003	0.99	0.3220	Not Signif.
Wing Fuel	0.013	2	6.420E-003	1.92	0.1507	Not Signif.
Fins configuration	0.015	1	0.015	4.39	0.0381	Significant
Mach-Wing Fuel interaction	0.024	2	0.012	3.56	0.0310	Significant
Residual	0.45	136	3.345E-003	/	/	/
Correlation Total	1.25	144	/	/	/	/

Table 3: ANOVA for Response Surface Reduced Cubic Model – Analysis of Variance Table [Classical Sum of Squares –Type III] – LCO Frequency

The significant main factors for LCO frequency response were ambient static pressure, Mach, fin configuration, and the second-order Mach and wing fuel interaction. The frequency level was related to the LCO amplitude.

Equation 2 represents the LCO frequency model. In this equation the coefficients show the relative influence of different variables on LCO frequency. The variable values have been normalized to coded factors between -1 to +1.

LCO Frequency = 
$$-0.185*(Mach) - 0.034*(ambient static pressure)$$
  
 $-[0.023 \ 0.031]*[second-order Mach-wing fuel interaction1 second-order Mach-wing fuel interaction2]^T + 0.011*(fins configuration) + (marginal factors contribution) (2)$ 

Based on the relative weights of the coefficients shown in Equation 2, the contribution of Mach number to LCO frequency was the most important, followed by ambient static pressure, the second-order Mach and wing fuel interaction, and Fins configuration.

#### 3.3 LCO Growth Rate - Surface Response Analysis

The results from the ANOVA analysis for the LCO growth rate response are shown in table 4. The Model F-value of 3.99 implied the model was significant and there was less than a 1 percent chance that a model F-value this large could occur due to noise. The small p-values, less than 0.05, for Mach, normal acceleration, wing fuel and second-order mach and normal acceleration interaction and ambient static pressure squared mean these variables were significant factors in the model. The lack of fit F-value of 0.50 implied the lack of fit was not significant relative to the pure error and there was a 95.14 percent chance that a lack of fit Fvalue this large could occur due to noise. Non-significant lack of fit meant that the model fit the actual data very well. The R-squared value of 0.1921, Predicted R-squared of 0.0706, Adjusted R-squared of 0.1439 and Adequacy Precision of 9.480 showed the model is suspect for the analysis purposes.

Source	Sum of Squares	Degree of Freedom	Mean Square	F-value	p-value	Significance
Model	1.34	9	0.15	3.99	0.0001	Significant
Ambient Static Pressure	0.034	1	0.034	0.92	0.3402	Not Signif.
Mach	0.29	1	0.29	7.90	0.0056	Significant
Normal Acceleration	0.61	1	0.61	16.36	<0.0001	Significant
Wing Fuel	0.33	2	0.16	4.41	0.0137	Significant
Fins configuration	0.044	1	0.044	1.19	0.2778	Not Signif.
Mach-g's interaction	0.19	1	0.16	5.17	0.0244	Significant
(Ambient Static Pressure)^2	0.18	1	0.18	4.881	0.0298	Significant
Dynamic Pressure	9.996E-003	1	9.996E-003	0.27	0.6052	Not Signif.
Residual	5.62	1151	0.037	/	/	/
Lack of Fit	5.05	143	0.035	0.50	0.9514	Not Signif.
Pure Error	0.57	8	0.071	/	/	/
Correlation Total	6.96	160	/	/	/	/

Table 4: ANOVA for Response Surface Reduced Cubic Model - Analysis of Variance Table [Classical Sum of Squares -Type III] - LCO Growth Rate

The significant factors for the LCO growth rate response were Mach, normal acceleration, wing fuel, the second-order Mach and normal acceleration interaction, and the squared value of ambient static pressure. The second-order Mach and normal acceleration interaction was predicted during the testing phase, due to the different LCO characteristics shown by the aircraft at increased load factor for different mach numbers. A similar result was found for the LCO amplitude response. Depending on Mach number the effect of "pulling g's" was different. At low Mach, increasing load factor, the LCO amplitude increased and then decreased, sometimes LCO damped out. At high Mach, increasing g's increased the LCO amplitude, sometimes reaching the termination/abort level. Based on the LCO growth rate before and after air refueling, a significant wing fuel influence on LCO was predicted and confirmed by the statistical analysis. Dynamic pressure, ambient static pressure, and fin configuration were not main factors, but due to their respective interaction effects they were not removed from the model. The squared value of static ambient pressure was found to be significant by the ANOVA analysis.

Equation 3 represents the LCO growth rate model. In this equation the coefficients show the relative influence of different variables on LCO growth rate. The variable values have been normalized to coded factors between -1 to +1.

LCO growth rate = 
$$-0.12*(second-order Mach and normal acceleration interaction)$$
  
 $-0.078*(Normal Acceleration) +0.074*(Ambient Static Pressure)^2$   
 $+[-0.083\ 0.033]*[WingFuel1\ WingFuel2]^T$   
 $+0.023*(Mach) + (Marginal factors contribution)$  (3)

Based on the relative weights of the coefficients shown in Equation 3, the contribution of second-order Mach and normal acceleration interaction to LCO growth rate was the most important, followed by normal acceleration, squared ambient static pressure, wing fuel, and Mach

The fins configuration was not a main factor for the LCO growth rate.

#### **SUMMARY**

A quantifiable difference in minimum LCO Mach number and LCO wingtip acceleration amplitude was found between fins on and fins off configurations. For the SL1 configuration with the dummy AIM-9s on stations 2 and 8, minimum LCO onset occurred at significantly different Mach for the fins on configuration versus fins off. This trend reversed when the dummy AIM-9s were carried on wingtip stations for SL2 and SL3. LCO amplitude increased with increasing Mach number. Fins configuration did not appear to have an effect on LCO frequency.

A statistical analysis was conducted to determine which variables had a significant effect on LCO. From the statistical analysis, the significant main factors for the LCO amplitude response were ambient static pressure, Mach, wing fuel, fins configuration and the second order interaction between Mach and normal acceleration. The LCO frequency response had all the same main factors as LCO amplitude, with the only difference being the second order interaction between Mach and wing fuel instead of Mach and normal acceleration. Finally, although not required by the Test Plan, the operationally representative response of LCO growth rate was analyzed. The significant factors for this response were Mach, normal acceleration, wing fuel, the second order interaction between Mach and normal acceleration, and the squared value of ambient static pressure.

These data were provided to AFSEO, who is using the flight test results and statistical analysis to update their current aerodynamic models in order to better understand, and more accurately predict, LCO.

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# Situational Awareness, Safety and Surety

by

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## ABSTRACT

Situational awareness is a complex and nebulous concept which may be better understood by breaking it down into several characteristics which combine to approximate "total" awareness to the flight environment. Although "Total Awareness" is an unrealizable goal (like "zero" accidents) improvements are within easy reach of today's technology. To evaluate possible improvements, this paper explores the make-up of the pilot's perception and comprehension envelope:

#### Positional awareness:

Pilot misinterprets nav equipment; Equipment error

#### Circumstantial awareness:

Things the pilot has no knowledge or control over

## Consequential awareness

Pilot may have knowledge but use it inappropriately

With integrated cockpits and diagnostic systems, thinking *ahead* of the aircraft no longer guarantees adequate crew awareness. The pilot must now think beyond the aircraft, adding the dimension of systems insight to the awareness equation. When an erroneous (or omitted) keystroke can cause an accident it is time to revisit our basic cockpit design precepts.

#### Situational Awareness, Safety and Surety

Surety is an insurance term that can be very appropriately used in aviation. Awareness and successful management of the flight situation is the insurance to which passengers are entitled when flying on an airplane. In the course of the past two or three years this insurance has been threatened by an unusual and alarming trend. That is: with the exception of the odd bomb or explosion, most recent airplane accidents have involved *relatively new* aircraft. Because FAA certification consists of evaluating new designs, this trend reflects badly on what we've been doing for the last ten years or so. It is (figuratively speaking) beginning to ring alarm bells in airline cockpits throughout the world. Air France 447 is a prime example.

It is well known that a good portion of the airline fleet is becoming quite old, and several accidents in the early 1980s asnd 90s reflected the need for improved maintenance and inspection of older aircraft. We, as designers and regulators anticipated an increase in the "aging airplane" accident rate, and planned to prevent it. This planning has had considerable success so far, because subsequent accidents of older airplanes have been rare.

What we have seen, on the other hand, is an unexpected increase in the accident rate for relatively *new* airplanes. So it goes without saying that we've overlooked something. That "something," I believe, is that we have *engineered* the pilot out of the cockpit. The trend for recently designed cockpits has been toward the pilot having more free time, through automation, to monitor and manage systems. Of course he still has a role to play, but the plan for a 'systems manager' that oversees airplane operation seems to have backfired. The systems are now managing the manager.

In early aviation, if your engine was running and you could see the ground your Situational Awareness was good enough. Today, however, airplanes have become increasingly complex. This complexity has come to include software that controls everything: the engines, the flight controls, navigation, maintenance, warning systems and much, much more. The pilot must continuously control the energy state and position of the aircraft with respect to obstacles around the desired flight path while at the same time monitor the functional status of all equipment and systems that affect flight. We have gone from spinning iron gyros to synthetically-derived software-based video displays in just a few years, and the amount of information today's pilot receives from these displays has become overwhelming.

A more holistic approach to Situational Awareness requires knowledge of what's going on inside and outside the aircraft, in order to have the complete picture of the "situation." The pilot needs enough information for good Situational Awareness, but not so much information that he can't get to the information he needs when he needs it. There are so many aspects to "Situational Awareness" that it is easy to lose sight of the important points. Failure to check weather, failure to turn around when entering bad weather, loss of control due to an emergency - all are situational events but lie within the realm of common sense and training. The intent of this paper is to identify design-induced Situational Awareness problems which, if corrected, will improve Situation Management.

Every airplane accident ultimately ends with the airplane hitting the ground, either in a controlled or uncontrolled fashion, and it can be argued that poor "Situational Management" is a prime contributing factor. Even in *uncontrolled* flight-into-terrain cases, adequate forewarning might have prevented an unrecoverable situation: in-flight breakup could be prevented by turbulence prediction or structural monitoring; mid-air collisions can be prevented by warning systems; even sabotage can be prevented with sophisticated detection systems. Controlled flight into terrain is much more subtle and is often a result of our attempt to make life easier through automation or 'better' display systems. All pilots train to "manage situations," but remain at the mercy of the designers in the area of Situational Awareness. Situation Management is very easy in modern airplanes; designers have built-in good flying qualities and accurate, reliable equipment. However three recent accidents in the same type of "newer" aircraft should serve as a wake up call for pilots and designers alike.

Situational Awareness is a nebulous and complex subject which may be better understood by breaking it down into some of the many characteristics which combine to approximate "total" awareness to the flight environment. Although "Total Awareness" is an unrealizable goal (like "zero" accidents) some improvements are within easy reach of today's technology. In order to evaluate possible improvements this paper explores the make-up of the pilot's perception and comprehension envelope and how design-induced Situational Awareness problems occur.

#### Positional awareness

The common (and most simplistic) view of Situational Awareness is nothing more than the knowledge of one's location in space; for want of a better term I call this Positional Awareness. Inadequate Positional Awareness can be as simple as pilot misinterpretation of navigation systems, or the equipment may be in error. And what is inadequate in one flight regime (e.g. a 200 ft. altimeter reading error when landing) may be perfectly acceptable in another (up-andaway cruise). The sum total of positional accuracy is called "flight technical error" and defines an envelope of varying size around the aircraft. It is only when this 'sphere' exceeds a predetermined size or intrudes on an obstacle in the flight path that awareness of the situation becomes critical.

On December 5, 1974 TWA flight 514 crashed into Mount Weather in Virginia, on approach to Washington D.C. The sphere of required positional awareness had become enlarged along the flight path as a function of low altitude, high speed and rising terrain. Coincidentally, the pilot had turned navigation of the aircraft over to Air Traffic Control with the tacit assumption they were aware of the high terrain. This accident resulted in the FAA requirement for Ground Proximity Warning Systems (GPWS) which detect high closure rate towards terrain. Although these systems have greatly reduced the number of CFIT accidents, they still occur.

<sup>1</sup> Controlled flight-into-terrain (CFIT) or uncontrolled flight-into-terrain (UFIT)

Another airliner equipped with GPWS and sophisticated Flight Management Systems<sup>2</sup> deviated slightly left of course and crashed into mountains on let down into Cali, Columbia. The flight crew knew their position accurately but was preoccupied with programming the FMS for the approach and unaware that the FMS had turned them toward high terrain. While this accident has given us a new technology, Enhanced GPWS,<sup>3</sup> it clearly demonstrates the shortcomings of the "pilot as systems manager" concept.

The Cali accident also demonstrates another shortcoming of modern airplanes. When information comes from a database and is displayed on a video display, we tend to believe it. We don't check computer-generated numbers and we don't cross check FMS-generated maps. Whether this is human nature or conditioning, we believe what we see on a computer screen. In the pureest sense software does not make mistakes, but there have been many, many cases where a software error or "bug" was missed in certification. The process of independent validation of software does not receive the attention it deserves. And of most importance, the compulsive nature of electronic displays cannot be overlooked when it comes to designing human factors in the cockpit.

#### Circumstantial awareness

A second and more complex meaning of Situational Awareness includes events that have occurred (or are about to occur) over which the pilot has no knowledge or control. These events usually are considered unavoidable (since by definition the pilot has no forewarning) and have catastrophic results if prompt action is not taken. In the past this has been where the "skill and cunning" of the pilot has come into play, with no small contribution from *luck*. This makes the civil aviation certification authorities squirm a little, since on the one hand we try to leave nothing to *chance* and on the other, we rely on probability analysis to determine what we certify by *testing* or what we accept by *analysis* only. The Failure Mode and Effects Analysis<sup>4</sup> has become a favorite tool in certification.

Examples of Circumstantial Awareness could be *loss of control* from unexpected forces (windshear, icing, control malfunction) even though the pilot is "in the loop" flying the aircraft. By far the majority of these events are merely "incidents" because pilots are generally very good at coping with the unexpected. However accidents continue to happen; Colorado Springs and Pittsburgh fall into this category, as do the Roselawn and Air France accidents.

More serious consequences of poor Circumstantial Awareness result from failures that cannot be dealt with, regardless of pilot ability. For example, there have been two recent accidents caused by uncommanded deployment of thrust reversers in flight, both on relatively modern airplanes. In fairness to the designers, the first accident was preceded by maintenance alerts which were not heeded, and the second was caused by the pilot overriding the mechanism designed to correct the problem. This leads one to believe that Circumstantial Awareness could be improved upon by implementing more effective detecting, alerting and correcting means.

<sup>&</sup>lt;sup>2</sup> A Flight Management System or FMS consists of multi-sensor position information displayed in the form of a map

<sup>&</sup>lt;sup>3</sup> EGPWS consists of conventional reactive GPWS plus a terrain database which anticipates terrain closure

<sup>&</sup>lt;sup>4</sup> FMEA - a statistical means of analyzing failure scenarios

#### Conditional Awareness

The third and perhaps most insidious 'awareness' category is the erroneous application of information which was intended to alleviate a problem: the pilot has adequate information but uses it inappropriately. It is an area over which we, as engineers, could exercise the most control. Unfortunately, we have chosen a less righteous path in the design of Warning and Display systems. We have chosen technology for its elegance rather then its effectiveness, forgetting that most pilots are not engineers and can be easily fooled by technology in a stressful situation. I call this case "Conditional Awareness," where the pilot may possess sufficient information to cope with a situation but it is used inappropriately.

One of the striking things about older flight decks is their very complex appearance; I don't know how many times I have heard non-pilots say "There sure are a lot of dials and switches! How do you ever remember what each one does?" Then look at a modern cockpit: two or three keyboards and a handful of TV tubes, all very neat and orderly. It looks wonderful, but as clean and simple as it appears, its beauty may be only skin deep.

For example, in old cockpits each abnormal situation is accompanied by a unique combination of annunciations. The geographical *location* of each light provides a cue to the affected system, so without conscious thought situational awareness is enhanced. In many new designs alerts are centralized and abbreviated. They must be read and understood before action can be taken; there are no subliminal cues. It is neat and orderly (it is said that *order* is the offspring of engineering) but 'order' is not always a good thing in Human Factors.

In the real world abnormal events usually do not occur in isolation: failures often have unexpected causes and unimagined side effects. When multiple failures occur in a modern cockpit, the pilot may be overloaded with non-prioritized information and is very likely to do the wrong thing. It is the job of Human Factors engineers to minimize this probability. Although training is the basis for safety, we train for the ordinary not the extraordinary: training scenarios are carefully rehearsed versions of probable occurrences. When improbable combinations of failures occur the pilot may do the wrong thing because of inadequate Conditional Awareness.

#### **Engineered Problems**

As keyboards replace knobs for data control, the use of single push buttons to access multiple functions has become a widespread practice. Behind each key or button lie many functions and menus which are hidden until needed, and multiple button pushes are required to accomplish a single, simple task. And, when the task must be accomplished in an emergency situation, the pilot's short-term memory may be occupied with other things. One can no longer look at an instrument or a panel and tell what action is required, and what used to be second nature now requires conscious effort. Cognition has replaced recognition in flight deck design.

Cathode-ray tubes and LED<sup>5</sup> displays have replaced mechanical instruments as a way of cutting cost and increasing information density (which is approaching the dangerous level). The use of electronic displays offers two options: make the display "look like" the old instruments we were accustomed to, or *innovate*. In attempting to retain the familiarity of old instruments, video display technology has enticed designers to produce displays that are not intuitive. Human factors *crutches* such as color-coding<sup>6</sup> and trend vectors<sup>7</sup> are necessary to prop up inadequate design and accommodate the "at-a-glance" readability needed by pilots.

In many of today's state-of-the-art cockpit designs, critical warning messages share space with routine engine data on a central video screen. This results in limited space available (typically between 15 and 20 characters) to display alerts. Abbreviations become necessary and lack of standardization often results in confusion over what an alert means; this particularly causes turmoil with non English-speaking crews. This can lead to a pilot taking the wrong action, which can be more hazardous than no action at all.

From the early 1980s to the present there has been a move toward a design concept loosely called the "dark cockpit." Designers were given the problem of minimizing the distractions caused by *unnecessary* annunciators in the cockpit, a formidable task when you consider that *all* annunciators have *some* purpose. This sometimes results in withholding too much information, the thinking being "the darker the better." This is not a healthy situation and the "dark cockpit" can easily become the "deaf and dumb" cockpit. Because the requirement to display information is usually based on the probability of needing it, situations statistically deemed "extremely improbable" are not always required to be annunciated. As a result, the withholding of information is determined by probability analysis. Non-pilots are therefore making decisions about what a pilot does or does not need to know. While this may be neither good nor bad, as systems become more and more self confident dark cockpit design has the potential to do precisely that: keep the pilot in the dark.

#### **Engineered Solutions**

There are two schools of thought in solving the Situational Awareness problem: 1) take the pilot completely out of the problem-solving loop, or 2) leave the pilot in control but enhance the decision making process. Examples of the former are GPWS, TCAS, and Windshear detection. Each of these systems has been very successful by providing warning and active guidance to the pilot, reinforced by compelling aural commands. The second approach uses new technology to advance warnings enough to allow informed pilot decision-making; examples are predictive windshear detection systems and Enhanced GPWS. Each has demonstrated merit in its own right and in combination with the others. Actually there is a third possibility: to automate the whole process, but this has not been given serious consideration and would meet with strong resistance from the pilot community.

<sup>&</sup>lt;sup>5</sup> Light Emitting Diode Displays or "flat plate display" take up less space and use less power than CRTs

<sup>&</sup>lt;sup>6</sup> Colors are used primarily to differentiate between normal and abnormal data

<sup>&</sup>lt;sup>7</sup> a non-intuitive display can be enhanced by a trend cue, giving direction to one dimensional data

<sup>&</sup>lt;sup>8</sup> Extremely improbable is statistically defined as a one in one billion occurrence

The problem of too much information is becoming more serious as microprocessors become more powerful. High information density (too much data in a small space) may be acceptable when situations are normal, but we must compensate for compressed data by expanding critical data when abnormalities occur. Use of 'windows' or other video tricks should be encouraged. Geographical or zonal display of alerts should be utilized to reinforce the abbreviated words on the central alert display. Would it not be better to orient annunciations to the cockpit zone where the corrective action takes place, instead of on a central warning screen? Or perhaps use pictures instead of words for alerts: we are held captive by our language. Truly synthetic vision9 and interactive alerting systems (such as virtual reality diagnostic displays) are being developed.

In developing operating procedures, it has always been assumed the pilot will follow them correctly. However emergency procedures are not always intuitive, and System Safety Analyses should take into consideration the pilot doing the wrong thing, as well as the possibility of the pilot waiting too long or perhaps taking no action at all.

Airplanes and systems must be "certified" that they meet minimal safety requirements before entry into service. In the past, when technology moved more slowly, regulations evolved in parallel with new developments; this doesn't work well any more. In recent years FAA has relied on "proof of concept" certifications for new technology, prior to granting across the board approval. While this has led to much smoother entry into service for new systems, much remains to be done to achieve good human factors.

#### Summary:

Looking at airplane accidents in the beginning of the jet-age, the major causes were systems unreliability and poor handling qualities. Over the years designers have corrected these shortcomings because it was within the state-of-the-art to do so, and it was profitable. Human Factors was pretty much ignored, partly because pilots don't complain, but mostly because it is a very difficult design area and Human Factors does not sell airplanes like technical innovation does. So it should come as no surprise that many of the accidents today are caused by poor Situational Awareness.

When operating integrated cockpits and diagnostic systems, thinking ahead of the airplane no longer provides sufficient awareness. The pilot must now think "inside" the aircraft, and at the same time maintain external awareness in a fast moving environment. The pilot must be aware of the status of the software as well as the condition of the airplane. The added dimension of Systems Analysis to normal flying duties greatly complicates the Awareness equation. We have made airplanes very complex: the level of Situational Awareness must increase in proportion to the greater complexity, either through "smart" machines, better Human Factors or in combination.

Unfortunately, experience has shown that smart systems do not necessarily result in improved Human Factors. We are walking a fine line between giving pilots adequate data to cope with a "situation," or providing so much information as to be distracting from the task at hand.

<sup>&</sup>lt;sup>9</sup> A truly Synthetic Vision System may consist of a computer-generated display that has been "verified" by external sensors such as infrared, radar or lasers

We now rely almost totally on statistical analysis to determine what we *Accept by Analysis*. The statistical approach certainly *must* be used to determine what needs testing, but it should be used cautiously when determining what *does not* need testing. When a wrong keystroke or misplaced decimal can *cause* an accident it is time to revisit our growing preoccupation with the analytical approach to airplane design and certification.

Finally, training has always been considered the basis for air safety, but the very need for training is indicative of a *less than perfect* design: the more training required, the more imperfect the design. And regimentation has traditionally formed the basis for training, which unfortunately does not contribute much to the *creative thinking* that is paramount to improved Situational Awareness.

#### Final thoughts:

"Knowledge is more important than information"

"Too much automation makes the brain relax"

"Better" is the enemy of "good"

# RefleXions by Harry Schmidt

# Kelly Johnson said the P&W J58 powering his SR-71 "Blackbird" was a "marvelous development, the only engine of its kind in the world." He was right.

That the SR-71 (and its predecessor the A-12) were the most technologically challenging aircraft and engine design concepts in history is unchallenged. And the fact that the US Government (really the CIA) turned over design of this revolutionary aircraft to Kelly Johnson and his world-famous Skunk Works at Lockheed was not unremarkable, for Kelly had designed a series of the best fighters in the world ... starting with the renowned P-38 during WW-II; to the design of America's first operation jet the F-80 (he completed design and construction within 180 days of program approval!); to the design of the F-104, the world's first Mach 2 aircraft; followed soon after by the design of the U-2 with the P&W J57 and J75 engines, the high flying spy plane (which Gary Powers made famous in 1960). In the late 1950s the CIA decided their U-2 was going to be increasingly vulnerable to Russia's advancing technology with ground-to-air missiles and thus they needed an improved reconnaissance aircraft that operated more stealthily, faster and higher than the U-2 to evade future missiles during the height of the cold war. Preliminary performance objectives included a stealthy design, long range, supersonic cruising speeds, and a cruise altitude above 75,000'. If anybody could do it, Kelly was the guy. But first he had to survive a competition with Convair (see Note 1). The CIA told Kelly that this was supersuper top secret and to respond to them when he felt confident that he had a solution. The project was deviously code-named "Oxcart".

Although initially looking primarily at increased stealth, Kelly became convinced that high supersonic speed was the ultimate answer ... and he meant really high speeds, such as Mach 3 (very soon after the industry had broken Mach 2). Of course he had to overcome several obstacles in his way, primarily that of heat, since the airframe at Mach 3 would be heated to 500 to 1000 degrees F, and that is pretty hot. But of even greater importance was what engine Kelly would use to power this manned missile? He knew that GE had supplied a supersonic engine (the J93, a 29,000# thrust engine with A/B) for the ill-fated B-70 Mach 3 supersonic bomber (designed to carry 300,000# of fuel and fly 5000 miles ... see Note 2).

Note 1: The CIA desired a more stealthy reconnaissance design than the U-2. Lockheed and Convair offered proposals. Convair had earlier offered a version of their B-58, with their final offer the Kingfish, a substantial redesign of their F-106 with 2 J58 engines imbedded in the fuselage. The CIA eventually chose Lockheed's Skunk Works for the task, largely on the basis of having found them to run tight on-time and on-budget development programs, and, of course, Kelly Johnson's acknowledged notoriety. Over the design period Lockheed offered 12 different aircraft designs, the first being the A-1 and the last being the A-12. The CIA accepted the A-12 version.

Kelly had also known of P&W's innovative efforts to develop a more advanced engine using a revolutionary new concept which at the time he did not fully understand. Since P&W seemed to be leading the aviation world in advancing engine technology for the prior decade (witness the J57 and J75 engines), first Kelly wanted to know what they could offer that might fit the requirement. His revolutionary aircraft (to be) would need an equally revolutionary engine.

The SR-71 would be a follow-on to the A-12, a single seat reconnaissance design, which had first received a production contract for 13 aircraft. Later Lockheed offered a two seat reconnaissance version with greater fuel capacity, then called the SR-71 Blackbird, with more range than the A-12, which the CIA preferred. A total of 32 Blackbirds were built.

P&W had earlier designed an engine for the WS-110 supersonic bomber (the predecessor to the B-70), originally with 4 engines, and offered the J91 as their submission. P&W had also intended that the J91 could evolve as their entry into the Princess flying boat nuclear program. The J91 was a 9 stage axial flow compressor single shaft engine envisioned to offer Mach 3 capability. From the J91 P&W later offered a ¾ scaled engine they called the JT11, an engine entered into the earliest US SST competition (in the late 1950 □s, see Note 3). The JT11 was also offered later for the WS-110 program when it became the 6 engine B-70 supersonic bomber, but P&W changed the designation to the J58 for that submission. The JT11 had an additional advantage it could be run successfully in P&W □s high altitude test cell in their (privately funded) Wilgoos laboratory.

Early in the A-12 design process Kelly met with Bill Brown, P&W's head of their J58 program, and learned more of this engine:

- Bill traced the background of the J91, JT11 and J58 programs. When GE won the B-70 competition, P&W continued limited development under internal funding. A short time later, in 1956, the Navy wanted a Mach 3 fighter. Vought proposed their F-8U-3 with either a new P&W JT11 (now called the J58) or the older J75. P&W received funding from the Navy for further development work on a refined version of the J58. Although the F-8U-3 (with only a J75 engine) easily won an abbreviated performance competition against the McDonnell F-4 powered by the J79, the Pentagon decided they preferred a 2-engine 2-seat F-4 model to a single engine single seat F-8U-3, despite the F-8U's performance advantage. The J58 program was then halted even though a prototype was in ground tests in Florida.

Note 2: The B-70 program flight program was cancelled for a variety of reasons including: a/t the USAF fear that it could be destroyed by Russian missiles if flying at high altitudes, suggesting that it would be preferable for the a/c to fly at very low altitudes to avoid detection but over much shorter distances, and, b/t the crash of one of only two B-70s in existence at the time during a photo-op when taking pictures of an F-104 flying formation with the B-70. The F-104 inadvertently collided with the right wing of the B-70 and both aircraft crashed and two of the three pilots on board the two aircraft were killed.

Note 3: As the US SST competition progressed, P&W concluded that a turbofan engine with a fan bypass duct augmenter was more suited to the SST mode of operation and focused its effort on the design and early development of such an engine then called the JTF17.

- The senior P&W design engineers had looked at a multiple of design concepts to power that Mach 3 fighter. One concept was to merely scale-up their trusty and reliable J75, already proven as a Mach 2+ powerplant in the F-105 and F-106, to be capable of producing over 26,000# of thrust with A/B. That would provide sufficient power for the new fighter. However, they were convinced that the J75, like the GE J93 (which was merely an upscaled version of their J79), both being straightforward axial flow turbojet engines with afterburner, wasn't the right engine for the mission. P&W experts knew that that basic turbojet design suffered increasing performance degradation at speeds approaching Mach 3. So you might (maybe) get to Mach 3, but due to performance erosion you wouldn't go very far. Moreover, afterburning turbojets were never designed for sustained cruise at high Mach, and the SR-71 was conceived as flying for over an hour at Mach 3+, necessarily in afterburner the entire time. So P&W had earlier convinced themselves that a new approach was clearly needed, however details of that new engine were not yet finalized. Kelly told Bill to keep him involved as their design optimization process evolved.
- In order to provide a home for this new engine (and another super-secret engine, the Suntan 304 – see Note 4), away from the confines of crowded Hartford, P&W had acquired a vast track of Florida swamp lands near West Palm Beach from the State and developed their new R&D facility where local residents (who might complain) were out-numbered by the alligators (who don't complain).
- After P&W experts had concluded the above, they set out to find a solution. They started with an analysis of the prototype J91 and concluded that the engine could not reach Mach 3 because the front stages of the compressor would become stalled at very high Mach and the rear stages would be choked. Moreover there was no air moving through the engine to cool the A/B liner which would therefore melt. Under Norm Cotter, P&W's chief of performance evaluation, a bright young engineer, Bob Abernathy, noted that their recent solution to compressor stall problems with the J57 and J75 was to open the bleeds to divert air around the compressor. He theorized that they could do that with the J58 at high speeds achieving three important objectives 1/ solve the surge problem in the compressor, 2/ provide cooling air for the A/B, and, 3/ increase thrust (later found to be an increase of 20% more thrust).

Note 4: The 304 Suntan project was a liquid hydrogen concept, originally designed for another CIA black project, a future Mach 2.5 surveillance aircraft capable of operating at 100,000'. The 304 was a so-called hydrogen expander cycle with a variable stator compressor driven by a 24 stage turbine that derived its energy output by the expansion of liquid hydrogen from -460 degree F to a gas. There was an elaborate heat exchanger behind the turbine which obtained heat energy from the combustion of the compressor air with gaseous hydrogen exhausted from the turbine. The 304 program started in Hartford under Bill Sens' group then transferred to FL around 1957 under Coar and Mulready. While that concept was terminated (due to the large volume of liquid hydrogen required), the technology that evolved from the 304 in the use of cryogenic liquid hydrogen (eg. pumps, heat exchanger design and construction) later became the basis for P&W's very successful rocket engine, the RL10, powering many of the USAF's most successful space explorations.

In essence his proposal would convert the turbojet into a ramjet at high speeds and should permit flight above Mach 3. The turbojet would power the aircraft up to about Mach 2, and then the ramjet would power the aircraft up to and beyond Mach 3 (see Note 5). And one of the interesting features was that their studies suggested that ramjet efficiency did not drop-off at higher speeds as it did with almost every other propulsive source. Moreover, their new ramjet could probably get significantly beyond Mach 3 (possibly with even reduced fuel flow per mile due to high aerodynamic heating requiring lesser amounts of fuel to be added in the afterburner ... a win-win situation). It was later (unofficially) reported that the fastest an SR-71 did fly was Mach 3.6, substantially beyond the design max of Mach 3.2. The max speed for the SR-71 would be determined by engine temperatures ... either a max of 800 degrees compressor inlet temperature (for hotter than that and the compressor blades would melt), or 3000 degrees in the tailpipe (for hotter than that and the A/B would melt).

- Bob, Norm, Bill Brown and Bill Sens were in agreement about the turbojet/ramjet design concept and Brown notified Kelly Johnson of their decision. Now that Kelly finally had a Mach 3 engine for his new reconnaissance aircraft he went to the Pentagon and quickly received a go-ahead and funding for the A-12. Brown told Kelly that much of the engine would be operating between 1000 and 3000 degrees F and thus Pratt would have to find some combination of new materials and advanced cooling systems designed to handle that super-hot environment, while also finding fuels and lubricants that could effectively perform at those elevated temperatures. P&W started off with a redesign of P&W's JT11-5A, a 32,800# afterburning engine with Mach 3+ capability.

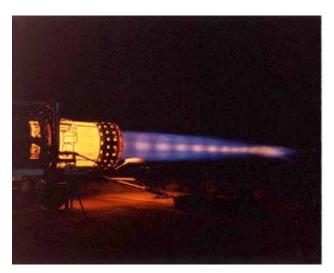
OK, so now that P&W had been selected, how did they handle this tiger they had by the tail... how to get metals working in 2500+ degrees, get appropriate fuels and lubricants, how to build a turbojet engine within the structure of a ramjet, and how to meet a short timetable?? Reasonable success with the earlier but smaller prototype gave them some confidence, but many serious questions remained and having the top secret CIA as a demanding client, with a cold war simmering in the background, added urgency and complexity to the task.

*Re: program management.* At the very beginning of the Lockheed/P&W joint program, both they and the Government agreed that a very close working relationship featuring engineer-to-engineer communications with a minimum of formal reports was the optimum process. It was adopted and worked very well.

Note 5: In the late 1950's P&W did extensive studies and conceptual designs of so-called turboramjet engines that could power recoverable, horizontal takeoff aircraft that could carry and launch the space vehicles conceived at that time to operate at sub-orbit altitudes. The so-called "aerospace plane" utilizing liquid hydrogen fuel would boost up to Mach 4.5 and launch the space vehicle. The tremendous heat generation from ram air at Mach 4.5 required "cocooning" and cooling the shutoff vanes at the inlet of the jet engine, hence the need for liquid hydrogen. The engine would operate as a ramjet above Mach 3+.

Re: materials. The obvious answer for higher temperatures was stainless steel and titanium. But neither material would hold up in the aft end when temperatures would approach 3000 degrees. After much experimentation P&W material experts developed a couple new materials, such as a nickel/cobalt alloy, Hasteloy X. They also developed a new forging process. In the past, when they tried to forge Astroloy disks for the turbine, the process caused segregated impurity clusters which decreased integrity and strength. They eventually concluded they could forge smaller ingots with a final forging at Ladish ... leading to the new "gatorizing" process, which led to the powder metallurgy now commonly used. Also, with the new cycle designed to bleed much cooler air around the hotter mid sections of the engine, much of that air could be later used for cooling in the hot back end via some fancy ducting. Similarly, all components, gears, bearings, weldings, etc. needed special design attention to allow them to operate in this environment. One example of extreme solutions ... early in the design the oil tank was gold plated on several early aircraft to increase heat dissipation, but that expensive solution was later retracted when other solutions were found.

See the J58 below in FL test stand. The white hot A/B vividly shows the extreme temperatures in the rear (see Note 6).



Re: fuels. Since the very high operating temperatures would instantly ignite JP4, converting the SR-71 into a short-lived pyrotechnic display, the engine required a new fuel, a fuel which literally would not burn. P&W, working with Ashland, Shell, and Monsanto, eventually manufactured a new fuel they called JP7 with very low volatility and a high flash point. It was also injected with nitrogen to further reduce its combustibility. However, since it would not easily burn, how would they start the engine? The answer was to use small amounts of triethylboron (TEB) to initiate burning, after which the fuel would burn by itself The aircraft would also have to carry a small amount of TEB during flight so that if an

Note 6: To simulate very high altitude and very high speed flight with the extremely high inlet temperatures associated with Mach 3 speed, P&W often placed a J75 in front of the J58, ran the J75 in A/B, and used the J75 exhaust as J58 air intake during ground tests in Florida.

engine flamed-out during flight and a restart were necessary, the TEB could be used for in-flight starts also. The TEB was also used to light the afterburner. The fuel had an additional use ... it was also used to cool the engines.

Re: flameouts. Indeed that became an operational problem. The inlets could (and often did) "unstart" during very high speed operation, and losing all thrust on one side created a large asymmetric thrust, obviously presenting severe operation problems as the aircraft yawed to one side amid substantial and violent gyrations which often unstarted the other engine. If not, pilots would often shut down the operating engine to reduce the gyrations and then restart both of them. P&W developed a stability augmentation system (SAS) designed to more quickly detect and thence to take corrective action when an unstart condition threatened. While the SAS helped, unstarts continued, although at a reduced frequency.

*Re: lubricants*: The primary lubricant was a silicone-based grease, normally a solid at room temperatures. Thus the engine had to be first heated before starting in order to liquefy the lubricant before engine rotation began.

Re: turbojet and ramjet design, in one engine? How did they do that?? Indeed this is exactly what the P&W engineers did ... 1/ they designed a straightforward 9 stage axial flow compressor single shaft turbojet (based upon the earlier but smaller JT11 design for the Mach 3 interceptor), and ... 2/ they diverted a majority of the air (about 75%) coming out of the compressor's 4th stage to flow around the engine and directly into the afterburner. The engine operated as a turbojet up to about Mach 2, at which point the engine automatically converted to a ramjet by bypassing compressor air directly to the afterburner where more fuel was added. The diversion of compressor air also reduced the total drag. Pratt estimated that 80% of thrust came from the ramjet and only 20% from the turbojet at elevated speeds. The engine also had a convergent-divergent (C-D) nozzle to provide additional thrust at supersonic speeds. The great success of the J58 was largely the result of this innovative "fan-assisted ramjet" configuration design... otherwise Kelly would have ended-up with merely a scaled-up J79 or J75 with decreased efficiencies at higher speeds, an inability to operate at sustained Mach 3 speeds, and an SR-71 of much reduced performance. It should be pointed out that this engine was designed in the mid to late 1950s when engineers primarily worked with slide rules and graph paper, assisted by "computists" (referred to as "engineering aides" who had excellent mathematical education and skills), not electronic computers.

Re: engine inlet. One of the tricky engineering details was to reduce air inlet velocity from highly supersonic speeds to under Mach 1, since the engine compressor could not handle supersonic air flows. Although "variable geometry" inlets had been known and used for a couple years on Mach 2 fighters to create a shock wave which would reduce inlet airflows below Mach 1, Mach 3 on the SR-71 presented a more formidable challenge. P&W eventually designed a conical spike which moved back and forth within the engine inlet ... in a forward position during low speed operation, but automatically withdrawn more than 2' into the inlet during high speed operation. This spike performed the required task of reducing the supersonic airflow speeds below Mach 1 by creating the desired shock wave in the inlet, but had to be very accurately positioned and carefully monitored in order to correctly form the shock wave.

Re: temperature effect. P&W knew that their J75 grew in length by about 1-2 inches when it got very hot, but also knew the J58 would grow much more than 1-2 inches since it operated at much higher temperatures (the final number was about 6 inches longer!). All parts of the engine would therefore have to be designed with substantial expansion to be expected during flight, but how to do that without destroying engine efficiency or operation (a turbojet requires close sealing between compressor blades and surrounding shrouds or it loses both efficiency and power), and how to calculate all that on a slide rule? That obviously took great engineering intuition and skills. Finally, how to connect an expanding engine to an also expanding airframe that was expanding at a different rate? (thus Kelly had to solve an engine-related problem of his own).

Re: airframe design. Since the Blackbird's airframe would also become very hot, it obviously expanded. To manufacture an aircraft capable of expansion Kelly took several steps: First was the extensive use of titanium (amounting to 80% of the weight), which material was surprisingly obtained primarily from Russia through various subterfuges (buying the titanium thru an intermediary concealing the fact that it was destined for a US secret aircraft). Another was to manufacture much of the wing in a corrugated configuration (a throwback to Ford Trimotor days) allowing the wing to expand during flight without cracking or stressing the thin metal skin. And finally, they manufactured the aircraft with very loose-fitting panels when cold on the ground, to become close-fitting panels when hot in high speed flight. Thus the aircraft continuously leaked fuel when cold on the ground but was tight (no leaks) when hot in the air. While Lockheed devoted significant efforts to making the SR-71 stealthy (less visible to ground radar), at high speed it generated such a large heat (infrared) signature (which was detectable by ground radar), it turned out that the SR-71's presence was clearly seen by radar systems from a long range allowing air defenses to attempt an interception, none of which succeeded.

Re: controls. They developed and used an electronic turbine temperature trimmer, which was the first use of electronic controls on a jet engine. After many improvements over the years the use of full authority electronic controls is now commonly used.

The spectacular SR-71 shown in-flight below.



Although P&W had a prototype running in the late 1950s, completing the design and construction of a larger engine for the SR-71 took several more years. It wasn't until 1964 that a final J58 was available for early flight testing, even though the airframe had been ready for two years. To provide an interim powerplant, P&W installed two J75s for early airframe flight testing. Larry Carlson was P&W's project engineer on this installation. The J75s were capable of powering the SR-71 well into the supersonic regime (about Mach 2) and provided Lockheed with initial airframe testing and validation. Most of this testing was performed at Area 51, also known as Groom Lake, the super-secret new flight testing facility that Lockheed had developed in the Nevada desert far from probing eyes. Lou Schalk (formerly a USAF test pilot in Fighter Ops at Edwards AFB) was Lockheed's test pilot on the early

A-12.

Special problems encountered during design and testing included:

1/ The engineers were encountering pipe failures attributed to a pressure "ripple" from the hydraulic pump. The solution was the utilization of a "Pulsetrap" to smooth-out the ripple.

2/ Kelly complained that there was too much thrust from the J58s at idle and the Blackbird was wearing out the brakes during taxiing. So P&W developed a low thrust/low idle solution, but the Skunk Works then complained that the higher idle speeds were necessary to run all their accessories. Thus they endured worn brakes.

3/ The J58 experienced compressor and turbine blade failures early in the program. After much experimentation they found that the compressor blade failures stopped when they stopped using Zyglo fluids for inspection. And later the turbine blade failures stopped when they started using Inco 718 material (as recommended by Joe Moore) which possessed 10% less density (the lighter weight reduced centrifugal forces) and greater durability than the earlier SM200 material. Inco 718 was eventually used in both turbine vanes as well as the first stage turbine blade to save weight, reduce cost, and achieve greater reliability (maybe the first instance of a solution saving weight, saving cost, and improving reliability at the same time).

4/ The flight test program required an expanded time schedule in order to optimize the complex and sophisticated inlets, the conical spikes, and their pushing the state-of-the art control systems necessary for prolonged Mach 3 flight.

5/ Foreign objects (FOD) was found to be the cause of substantial engine damage during early flight operations. Thus all runways were carefully inspected to remove all FOD, and the engines carefully inspected to remove material left behind.

To say that the Blackbird was an outstanding success is a gross understatement. It met every CIA operational need for intelligence and surveillance during many critical cold war events from 1964 through the next 25+ years. It was based in the world's hot spots (such as on Okinawa for many years watching developments in North Korea and Vietnam) and could be anyplace where international conflicts erupted in literally a few hours, taking high resolution photos from 80,000', and simply running away from any threats. They estimate that some 4000 missiles were shot at the SR-71 during its 2000+ flights over hostile

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terrain, but all the pilots had to do, they said, was to push the throttles forward to outrun the missiles since few missiles had both speed and altitude capability to threaten the SR-71. Additionally, pilots could turn the SR-71 rapidly just as the missiles were approaching, a maneuver the missiles could not duplicate. In later years, improvements to missile performance presented a greater threat to the SR-71 reducing its utility, although no SR-71s were ever lost due to combat actions. However, 12 were lost due to operational difficulties. Of the 32 built, the remaining 20 SR-71s are in air museums, all but one – that one in the UK – are in the US. All tools, jigs and fixtures used in construction were destroyed by White House (McNamara) orders in 1968 when construction was completed. The aircraft was withdrawn from active service on largely political grounds on two occasions, first in 1989 and then retired a second time in 1998. Detractors thought the cost was too high relative to satellite photos, but supporters cautioned that photos from space were taken on a predictable time schedule and therefore unlikely to yield substantial new and accurate intelligence. However, without data link the aircraft had no way of transferring real-time data back to the ground and this was a known and significant deficiency.

Early in the SR-71 program the USAF was looking for a Mach 3 interceptor. After the USAF rejected several others' proposals, Kelly Johnson suggested that he could convert his SR-71 (earlier called the A-12) into a suitable interceptor, and the USAF approved of his proposal. As a result, the USAF acquired 3 prototype interceptors, a two seat aircraft substantially modified from a reconnaissance role to an interceptor role possessing radar guidance systems, Hughes AIM missiles, etc. that was designated the YF-12. No further production contracts were issued ... indeed the YF-12, although very fast, was an unlikely interceptor needing special attention:

1/ much ground preparation time before takeoff,

2/ then requiring immediate refueling after takeoff and climb to altitude, including a dash to high speeds to get the skin hot and joints tight (to retain fuel), consuming an additional 15 minutes to transfer 90,000# of fuel, 3/ plus preparation time for the pilots to get into their pressure suits and breathe oxygen for a substantial time before takeoff,

4/ finally, prepositioning a refueling tanker with the special JP7 fuel.

Note: approximately 36 hours was normally required to prepare both the aircraft and crew for a standard SR-71 surveillance flight, although obviously in an air defense role much shorter procedures could have been developed.

The SR-71's superior performance is shown below comparing it with the record-setting Convair F-106 (all approximate figures):

	SR-71	F-106
Length	100'	70'
Span	55'	38'
Height	18'	20'
Engine (no. and type)	2 X J58	1 X J75
Max engine thrust	32,000#	25,000#
A/C weight (empty)	60,000#	24,400#
A/C weight (max TO)	170,000#	34,500#
Fuel weight	100,000#	10,000#
Engine weight/eng	2 X 6,200#	1 X 5,000#
Max range (at max speed)	2200 miles @ 3.2 M (7)	400 miles @ 2.4 M
Max range (ferry)	3000 miles (7)	1500 miles
Max cruise speed	3.2+ Mach	2.4 Mach
@ max cruise altitude	80,000'	40,000'
Fuel burn at max speed	7500 gals/hr/eng	
Crew	2	1

The wide improvement in performance of the SR-71 over the F-106 and all other contemporary aircraft is readily apparent from the above ... primarily the result of P&W's exquisitely designed J58 engines containing numerous innovative features, (although Kelly might argue that his innovative airframe design had something to do with the Blackbird's success). The fact that no pilots or aircraft were lost during the Blackbird development program due to engine failure was a tribute to the engine, and endeared P&W to Lockheed who remembered a number of lost aircraft and pilots from engine problems in earlier programs. The Blackbird holds almost every world's speed record, most set over 20 years ago. What a legacy for the airframe, the engines and their respective designers!

While Kelly Johnson became internationally famous for his several aircraft designs, as was appropriate, the equally talented P&W engine designers never received any acclaim. It is appropriate to remember such key engine designers and managers as Bill Brown, Dick Coar, Norm Cotter, Bill Gorton, Jack McDermott, Don Pascal, Bill Sens, etc., who all played an integral role in the J58 development and whose names were unfortunately lost amidst the ground mist shrouding all top secret developments, probably aided by P&W's corporate culture dedicated to personal anonymity. They should have received greater notoriety.

In his memoir, Kelly Johnson kindly commented on his friendly recollections of P&W's contribution to the SR-71 by stating ... "The powerplant for the Blackbird is a marvelous development on the part of Pratt & Whitney. It is the only engine of its kind in the world."

Note 7: The SR-71 would take-off with little fuel on board requiring refueling soon after takeoff and an initial dash to high speed to increase fuselage temperatures to properly seal the skin and prevent fuel leakage.

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Harry Schmidt 2011 References:

Jack Connors: The Engines of Pratt & Whitney, AIAA Press, 2010

Technical reviews by Larry Carlson and Ted Slaiby.

HPS 2/17/11

# 2012 SYMPOSIUM INFORMATION AND CALL FOR PAPERS

The Society of Experimental Test Pilots' 5th Southeast Symposium will be held on 23-24 February 2012 in Fort Walton Beach, Florida. Troy Fontaine (M) is the Chairman of this event.

This is an official call for papers. Presentations should be limited to 30 minutes, including the discussion period. No proceedings are published for this Symposium therefore formal written papers are not required. Those interested in presenting should submit an abstract by 16 January 2012 to:

Troy Fontaine, Symposium Chairman C/O SETP Headquarters Post Office Box 986 Lancaster, California 93584-0986 Email: Laurie@setp.org

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42nd Annual San Diego Symposium San Diego, California 23-24 March 2012

#### CALL FOR PAPERS

The 42nd Annual San Diego Symposium will be held 23-24 March 2012 at The Catamaran Resort Hotel & Spa, 3999 Mission Boulevard, San Diego, California

This is an official call for papers. Presentations should be limited to 30 minutes, including the discussion period. No proceedings are published for this Symposium therefore formal written papers are not required. Those interested in presenting should submit an abstract by 20 January 2012 to:

Ryan Howland, Symposium Chairman C/O SETP Headquarters Post Office Box 986 Lancaster, California 93584-0986 Laurie@SETP.org

# The Society of Experimental Test Pilots East Coast Section Symposium

## Call for Papers

The East Coast Section Symposium will be held on 13 April 2012 at the Naval Air Station in Patuxent River, Maryland.

This is an official call for papers. Presentations should be limited to 30 minutes, including the discussion period. No proceedings are published for this Symposium therefore formal written papers are not required. The deadline to submit an abstract has been extended to 9 March 2012. Please submit your abstract to:

> Klas "Santa" Ohman, Symposium Chairman C/O SETP Headquarters - Email: Laurie@setp.org Post Office Box 986 Lancaster, California 93584-0986

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## FLIGHT TEST SAFETY WORKSHOP

30 April ~ 3 May 2012

The Renaissance Seattle Hotel

Seattle, WA

The theme of the workshop is "I Learned about Flight Testing From.....". The committee is currently requesting papers and presentations highlighting those flight test events, people or programs which changed our way of thinking when we plan and conduct flight test. These may be unexpected results from routine "low risk" testing; unexpected "cliff" points; normalization of deviance; or other "surprises" which have occurred during off condition flights of experimental airplanes. The committee welcomes all Flight Test Pilots and Engineers to submit papers. Flight Test Pilots and Engineers new to the profession are encouraged to submit. Presentations should be limited to 25 minutes and every effort will be made to group similar test programs together in each session to maximize the lessons learned from the presentations. Please send paper/presentation proposals to the 2012 Flight Test Safety Workshop Chairman, Mr Gerald Whites via laurie@ setp.org. If you should have any questions regarding submitting an abstract please contact Gerald Whites at 509-846-3613. The deadline for abstracts is 1 February 2012 to allow time for appropriate consideration and inclusion in the program.

The Great Lakes Symposium will be held 17 May 2012 at the Wright-Patterson AFB Banquet Center in Ohio (formerly known as the Officer's Club).

This is an official call for papers. Presentations should be limited to 30 minutes, including the discussion period. No proceedings are published for this Symposium therefore formal written papers are not required. Those interested in presenting should submit an abstract by 24 February 2012 to:

Robbie Robinson, Symposium Chairman C/O SETP Headquarters - Email: Laurie@setp.org Post Office Box 986 Lancaster, California 93584-0986

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The Society of Experimental Test Pilots
European Symposium
Call for Papers

The European Symposium will be held on 23 to 27 May 2012 at the Kempinski Bristol Hotel in Berlin, Germany.

This is an official call for papers. Presentations should be limited to 30 minutes, including the discussion period. If you accept your paper to be published in the proceedings, formal written papers are required to be submitted by the time of the symposium. The deadline to submit an abstract has been set to 5 April 2012.

Please submit your abstract to:

Chris Worning, Symposium Chairman
Cassidian Flight Operations
Rechlinerstrasse
85077 Manching
Germany
christian.worning@cassidian.com

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5th Annual Central Section Symposium Hotel at Old Town ~ Wichita, Kansas 1 June 2012

This is an official call for papers. Presentations should be limited to 45 minutes, including the discussion period. No proceedings are published for this Symposium therefore formal written papers are not required. Those interested in presenting should submit an abstract by 1 February 2012 to:

SETP Headquarters Post Office Box 986 Lancaster, California 93584-0986 Email: Laurie@setp.org

# THE SOCIETY OF EXPERIMENTAL TEST PILOTS 56th SYMPOSIUM & BANQUET

Anaheim, California 26 -29 September 2012

#### CALL FOR PAPERS

The 2012 Symposium and Banquet will be held 26-29 September 2012 at The Grand Californian Hotel, California.

Abstracts should be a 50-word or more outline of the specific scope and highlight of your chosen topic. The deadline for abstracts is 31 May 2012.

PLEASE NOTE: PAPERS MUST BE TECHNICALLY-ORIENTED RATHER THAN SALES-ORIENTED. AVOID DIRECT REFERENCE TO COMPETING SYSTEMS. PAPERS CONCERNING FLIGHT TEST SAFETY ARE STRONGLY ENCOURAGED.

The Ray E. Tenhoff Award and cash honorarium will be awarded during the banquet program to the person presenting the best all-around technical paper.

Email or mail all abstracts to:

Attn: Mr. Pat Duffy Symposium Chairman **SETP Headquarters** P.O. Box 986

Lancaster, California 93584-0986 Email: laurie@setp.org

# MEMBERSHIP NEWS AND UPDATES

You should have received an email from SETP Headquarters offering the option of electronic invoice for future billing for those Members who pay annual dues. If you have not already done so, please respond to <a href="mailto:laurie@setp.org">laurie@setp.org</a> or call 661-942-9574 if you would like to go paperless. Please be sure to indicate which email address you prefer the invoice to be sent to.

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The Society of Experimental Test Pilots as well as the SETP Foundation and SETP Scholarship Foundation need volunteers to help with various committees and boards. Traditionally volunteers were identified through word of mouth but unfortunately many would-be-volunteers never knew that openings existed or how to volunteer for them. The SETP Board of Directors has decided to create and maintain a database of members who would like to contribute more of their time to the Society. If you are interested in volunteering, please e-mail Laurie@setp.org or mail to SETP, PO Box 986, Lancaster, CA 93584 with the following information:

NAME: EMAIL: PHONE:

Amount of time available (3hours/mo, 3 hours/ week...): Any special skill you may have (CPA, JD, Education experience, CEO experience...): Are you available to meet in person at SETP headquarters or do you intend to call in? Is there an SETP Committee you would like to participate in such as:

- Membership
- Publications
- Information Technology
- Test Pilot Value
- Test Pilot Role in UAV testing

Is there an SETP Foundation Committee you would like to participate in such as:

- Education/Mentoring
- Facilities
- Fund Raising/Finance/Legal
- Historical
- Public Relations
- Publishing
- Steering/Strategic Planning

Would you like to serve on the Scholarship Foundation Board? Are you interested in serving on the Board of Directors? Are you interested in being an officer in one of the local sections? Other information you feel may be helpful:

# NEW MEMBERS AND UPGRADES

The Society would like to welcome the following new Members:



Bevan, Edward (AM) Cessna Joined 19-Oct-11



Capovilla, Giordano (AM) Italian Navy, LT Joined 16-Nov-11



Cipelletti, Davide (M) Italian Air Force, LtCol Joined 14-Dec-11



Corneille, Daryl (PAM) USAF, Maj Joined 14-Dec-11



Elliott, Olivia (PAM) USAF, Maj Joined 14-Dec-11



Gentile, Christopher (PAM) USAF, Mai Joined 14-Dec-11



Hemmingsen, Martin (PAM) USAF, Maj Joined 14-Dec-11



Masten, Dustin (PAM) USAF, Maj Joined 14-Dec-11 July - December 2011 63



Maynard, Robert (AM) MIT Lincoln Laboratory Joined 16-Nov-11



Nichols, Clint (M) Scaled Composites Joined 19-Oct-11



Oliver, Michael (PAM) USN, LT Joined 14-Dec-11



Patterson, Todd (PAM) USAF, Maj (Select) Joined 14-Dec-11



Ruedinger, Markus (M) German Official Test Centre, Manching Joined 19-Oct-11



Stevens, Timothy (PAM) USAF, Maj Joined 14-Dec-11



Sweeney, Nicholas (PAM) USAF, Maj Joined 14-Dec-11



Verniest, John (M) USN, CDR Joined 19-Oct-11



Wilhelm, Thomas (M) GAF, Lt Col Joined 19-Oct-11



Wimer, Jeremy (PAM) ÚSAF, Maj Joined 14-Dec-11

## PHOTOS NOT AVAILABLE FOR THE FOLLOWING NEW MEMBERS:

Childers, Clark (M) **ETPS** Joined 19-Oct-11

Dunkle, Steven (M) **Northrop Grumman** Joined 19-Oct-11

Sabariegos, Luis (PAM) Spanish AF, Capt Joined 14-Dec-11

Clemence, Elliot (M) Lockheed Martin Joined 19-Oct-11

Helms, Jonathan (PAM) **ÚSAF**, Capt Joined 16-Nov-11

Shelton, Michael (PAM) USN, LT Joined 19-Oct-11

Swartzwelder, Matthew (M) USŃ, LT Joined 16-Nov-11

Congratulations to those members who have upgraded their membership!



Carter, Kristopher (M) USN, LT **Upgraded 19-Oct-11** 



Colmer, Jr., Gerald (AF) USAF, LtCol **Upgraded 19-Oct-11** 



Cowan, Adam (M) USA, CW4 Upgraded 19-Oct-11



Dietrich, Jonathan (M) UŚAF, Maj Upgraded 16-Nov-11



Ferguson, Ian (M) USAF, Maj Upgraded 19-Oct-11



Horne, Thomas (AF) Gulfstream Upgraded 16-Nov-10



Huff, Thomas (AF) USN, CAPT Upgraded 19-Oct-11



Hunter, Donald (M) USA, CW5 Upgraded 19-Oct-11



Johnson, Scott (M) USN, LT Upgraded 19-Oct-11



MacDonald, Adam (AF) USAF, LtCol Upgraded 14-Dec-11



Meyer, Paul (M) USN, LCDR Upgraded 16-Nov-11



Miller, Colin (AF) USAF, Col Upgraded 16-Nov-11



Robinson, Dwight (AF) USA, LTC Upgraded 19-Oct-11



Shubert, Martin (AF) **Bell Helicopter** Upgraded 19-Oct-11



Ryals, Samuel (AF) Goodrich Upgraded 19-Oct-11



Slager, Jonathan (M) USN, LT Upgraded 14-Dec-11

#### PHOTOS NOT AVAILABLE FOR THE FOLLOWING MEMBERS WHO HAVE **UPGRADED THEIR MEMBERSHIP:**

Cain, Charles (M) ÚSAF, Maj Upgraded 14-Dec-11

DeBons, Jeremy (M) USN, LT **Upgraded 19-Oct-11** 

Otsuka, Keith (AF) **Boeing** Upgraded 19-Oct-11 Cernan, Eugene (AF) USN, CAPT (Ret) Upgraded 16-Nov-11

Drake, David (AM) USN, LCDR Upgraded 14-Dec-11

Skennar, Barry (M) RAAF, FltLt Upgraded 16-Nov-11

Traynor, Devin (M) USAF, Mai Upgraded 16-Nov-11

# WHO...WHAT...WHERE

The US Congress recently bestowed its highest civilian honor on four American space pioneers of the 1960s. This is the first time the Congressional Gold Medal has been awarded to astronauts.

The honorees are Neil Armstrong, who was the first man to walk on the Moon; Buzz Aldrin, who was the second; and Michael Collins, who was the command module pilot for Apollo 11, the first manned mission to the Moon in 1969. The fourth was John Glenn, astronaut and former senator, the first American to orbit the Earth in 1962.

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FORMER SETP PRESIDENT ENTERS KENTUCKY AVIATION HALL OF FAME

**Edward T. Schneide**r, the youngest graduate of the US Navy Test Pilot School who made history as a test pilot, was honored with induction into the Kentucky Aviation Hall of Fame in Lexington on November 12, 2011.

Ed completed test pilot school at age 24 and went on to a career testing aircraft and making aviation history. Most of his flight testing was at the Dryden Flight Research Facility in California. His work was conducted in a number of experimental aircraft and test programs. He was the very first pilot to fly an aircraft with multi-axis, vectored-thrust propulsion, and conducted first flights in five unique research aircraft.

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**CAPT Tim Morey (AF)** recently retired from the U.S. Navy and has accepted the position of Senior Program Manager and Deputy Director of Flight Operations at Wyle's Camarillo, California location. Wyle specializes in high tech services for Aerospace, Life Sciences and Information Systems.



Change of Command Announcement - HX-21 - CDR William "Wade" McConvey, USN (M) relieved LtCol Thomas E. Post, USMC on 07 October 2011, NAS Patuxent River, MD. HX-21 is responsible for the Developmental Test and Evaluation of Navy and Marine Corps rotary-wing/tilt-rotor aircraft, airborne systems, and Unmanned Aircraft Systems.

# WANTED: MEMBER and CORPORATE MEMBER INFO AND PHOTOS!!!

Keep the members up to date on your Individual and Corporate news, events, and happenings!! The Society is soliciting flight test related news about SETP members and Corporate members for publication in the WHO...WHAT...WHERE section of COCKPIT Magazine. If you know of some interesting information about an SETP Member(s) or Corporate Member, please send it in. If you have some photos to accompany the news, all the better! All information and photos submitted will be given serious consideration for publication in COCKPIT Magazine. Flight Test events, awards, promotions, gatherings, etc. should be reported and shared.

> To submit news and photos please contact Becki Hoffman at 1-661-942-9574 or Becki@setp.org

> > **SETP Headquarters** P.O. Box 986 Lancaster, CA 93584

# KNOW THE CORPORATE MEMBER

# National Test Pilot School



The National Test Pilot School (NTPS) is a not-for-profit civilian educational institute located and incorporated in the State of California. What is often misunderstood is that NTPS is not owned by any person or group of persons but like most educational institutions is an independent entity governed by a Board of Trustees\*. The School was established in 1981 to meet the flight test training needs of both the US and international aerospace communities. NTPS students and customers come from a variety of backgrounds including military organizations, aerospace industry, governments, certification agencies, and even private citizens. NTPS is the only civilian school of the seven SETP recognized test pilot schools in the world.

The primary objective of NTPS is to educate and train test pilots and flight test engineers to be able to successfully plan and execute flight test programs for their military or civilian test and evaluation organizations immediately upon graduation. This objective is principally accomplished via our year-long Professional course which is uniquely presented by equally dividing the course into a Systems Phase and a Performance and Flying Qualities Phase. NTPS also has a broad domestic and international constituency for specialized flight test training and as such we offer over 30 unique courses, ranging from a variety of short courses to numerous academic-only courses.

NTPS offers a Master of Science in Flight Test Engineering and a Master of Science in Flight Test and Evaluation through its National Flight Test Institute (NFTI) Graduate Program. The Master of Science in Flight Test Engineering is accredited by ABET (Accreditation Board of Engineering and Technology). The degrees can be earned through a year-long professional course or through a traditional graduate academic track.

Located in the best flight test area in the United States, NTPS enjoys use of the R-2508 Complex in California which also encompasses Edwards AFB and China Lake NAS. NTPS utilizes a large variety of aircraft, simulators and laboratories, many incorporating the latest technologies in aircraft and mission systems.

NTPS employs a staff of highly experienced US and International flight test professionals as its instructional cadre with an average of twenty (20) years flight test experience and of ten (10) years of flight test instructional experience. The NTPS instructional staff has former members of US Army, US Navy, US Air Force, FAA, and numerous international air force flight test organizations and has graduates from NTPS, USNTPS, USAFTPS, ETPS, and EPNER.

The new NPTS management team and revitalized Board of Trustees\* are committed to enhancing the reputation and continuing the development of NTPS' education and training capabilities that provide a vital service to both the US and International flight test communities. Further information about NTPS can be found at www.ntps.edu or by calling (661) 824-2977.

\*The NTPS Board Trustees are Wendy Shawler, Walt Schob, George Marrett, Al Peterson, Tom Morgenfeld, Pat Garman, and George Cusimano. The NTPS President and CEO is Dr. Al Peterson, the Vice President and Director of NTPS is Mr. Greg Lewis, and the Director of NFTI is Dr. Terry Donovan.

# SECTION NEWS



## Northwest

# The Society of Experimental Test Pilots Northwest Section Presents

# MiG-29 Restoration & Flight Testing

at the

# Historic Flight Foundation

Paine Field (KPAE) 10719 Bennie Webber Drive, Mukilteo, WA 98275

John Sessions, founder of the Historic Flight Foundation will discuss the challenges and rewards of restoring and flying a MiG-29.

Saturday February 4, 2012 1:00 – 3:00 PM \$20/person \$30/family



MEMBERS & NON-MEMBERS WELCOME

Snacks and soft drinks will be provided.

Additional information and directions:

http://www.setp.org/northwest-section/northwest-section.html

http://historicflight.org/hf/contact/

Tom Twiggs 425 454 9238



# SCHOLARSHIP FOUNDATION **NEWS**

## **Scholarship Foundation Student Updates**

Just wanted to let you know how I'm doing...

As of two days ago, I've just completed the first year of my MA in Humanities: Literature. Since graduation last year, I have been teaching at two different music academies, as well as with charter schools--everything from geography to English to opera! The opportunities continue to open up.

In TWO WEEKS, I will be getting married to an airman stationed at Whiteman AFB in MO. (I guess I just couldn't stay away from the planes). It's a bittersweet transition, missing my dad and moving back into military circles. But I know this is where God has called me to be! I'm hoping to find my little crevice in the Whiteman community, where I can hopefully be a resource and an asset. I already have several engagements to teach music there (including the children of two colonels!) as well as an offer at a private school. I have two years left (God willing) on my first MA and have high hopes to obtain a second Master's in American history (emphasis: military history) before pursuing my Ph.D. I have about another ten years to go, if I'm lucky! As it turns out, I love to study.

Best wishes to you this holiday season. SETP continues to be a blessing to my family; I only hope you know what a difference you've made.

### Stephanie Brohmer \*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

I want to take this opportunity to express my gratitude for your support over this last semester. Because of it, I have been able to not only take classes necessary for my degree, but also reduce my work schedule to part-time. Several months ago I received a promotion to a position in Geek Squad, which is giving me practical experience pertinent to what I am learning in school.

At the end of the semester, I will have completed classes in networking, Windows operating systems and computer electronics. I also took an exam preparation class for the CompTIA A+ Computer maintenance and Repair Certification, which I am taking this week. By the end of next semester I will receive my Certificate of Computer Maintenance Technology from Saddleback College and by this time next year I will have earned my Associate Degree of Science.

Once again, thank you so much for your continued support for me and my family!

Warmest regards, Juliana Brohmer Hansen

### **SETP Scholarship Foundation** Current Status

### Purpose

"To ensure any eligible student\* that applies for financial aid is not prevented from obtaining a higher education due to financial shortfall."

### \*Eligible students are:

- children of deceased or disabled SETP members, attending a 2 or 4 year college or university,
- as a full-time student, with a 2.0 or better GPA.

Origin & Authority

- Organized in 1965 by the SETP and authorized by SETP Constitution (Article XIV).
- Non-profit, incorporated as a 501-c3 in the state of CA and operated under its own Bylaws and SOPs.
- Trustees appointed by the SETP Board and directed to operate independent of SETP (Bylaws Art. I Sec.3).

### History

- Early years were "hand-to-mouth" with annual fund raisers, raffles at the symposia, etc.
- Investments by 1985 totaled \$279,000.
- During late '80s & '90s, growth from donations and investments.
- Allen Paulson donated \$1 million in 1985.
- Then contracted w/ professional investment advisors to meet fiduciary responsibility to the members.
  - Staff support by SETP staff paid by Foundation.
- Ted Osinski (M) donated \$1 million in 2005.

#### Current Financial Status

- Total Awards since inception = \$2.3 mil.
- Total Students\* supported since inception = 156
- Total assets fluctuates with market, approximately = \$3.8 mil.
- Annual Awards for 2011= \$108K
- Annual Operating Expenses \$40-50K
- Currently 8 students in the program with 14 projected for the future
- \*To date, we have had students from six countries (France, Indonesia, Israel, Russia, South Africa, USA).

### New SETPSF Initiative

- Planned Giving Program to proactively seek donors to make more significant donations than in the past.
  - Ex. Bequest (by Will or Living Trust) or Charitable Gift Annuity.
  - Objective -
    - Grow the SETP Scholarship Foundation so that the grants provided to our students cover 100% of the cost of their education, and
    - Stay ahead of inflation.

# 55<sup>TH</sup> ANNUAL SYMPOSIUM & BANQUE **REPORT**

21 - 24 September 2011 Grand Californian Hotel, Anaheim, California

The 55th Symposium and Banquet was a great success, capitalizing on some excellent suggestions provided by the team from last year's symposium as well as incorporating solutions and improvements from the common critiques from last year's symposium. This year, we chose as a theme the Centennial of Naval Aviation (CONA), opening the Symposium with a movie honoring this rich history. Several of our symposium and session chairmen had their roots in naval aviation, and the crowd was presented with several historical videos and other tangible reminders of this rich heritage and its connection to the Society. Events were well attended, and registration was the second-highest in the last ten years at 662.

The Disney staff again did a fantastic job of hosting our event. Specifically, we sought significant improvement in the quality of the Friday Night Reception, and I received many compliments from SETP members during the weekend about the great work the Disney staff did in presenting Friday night. Disney really stepped up to the plate for the food choices and quality for every one of our meals and the effort was noticed and appreciated by our membership. Additionally, the speaker for the Friday Luncheon, Mr. George Whitesides (CEO, Virgin Galactic), gave an excellent presentation about the future of commercial space travel.

In keeping with our theme, the symposium kicked off with an absolutely spectacular tour of the USS Ronald Reagan in port down in San Diego. After the tour of this active carrier, the Technical Tour chairman took us to another aircraft carrier—the USS Midway—for a catered lunch on the flight deck accompanied by an entertaining and informative talk by the Midway's staff historian. The SETP staff provided refreshments for the ride, and I received not one complaint about the drive or the tour itself. Great way to start the weekend.

The corporate displays had the usual excellent look and were well-staffed by their sponsors. This year, however, we had the USAF Test Pilot School and the Navy Test Pilot School on board, joining the display of the National Test Pilot School. USAF TPS brought along their RASCAL pod and demonstrated its capabilities to the crowd.

The SETP Foundation put on a very-well attended briefing targeted toward members and spouses to prepare them for one of life's eventualities that might occur unexpectedly. The untimely deaths of SETP members—from both the USA and other countries—prompted the Foundation to prepare a briefing titled "Planning for Your Family's Future" and it included an exceptional handout, which is now posted on the SETP website. The briefing was attended by some 75 spouses and members and received very high praise.

Our educational outreach continues to grow in numbers and prestige due to the commitment of our outreach program leaders. The symposium was well attended by three of the six high schools invited and the students were recognized in front of the Society at the Friday Luncheon and during the technical session.

The Symposium Chairman received a flood of stellar papers—over 50—from which to choose to meet the goals of diversity and relevance as well as to fit the CONA theme. Critiques and face-to-face comments from the members indicated the chairman had scheduled an exceptional speakers program. A key component of the success of this slate of papers is our selection of winners and runners up from the various regional symposia

as well as soliciting papers from known test programs that might otherwise not present. Finally, the Saturday program was highlighted by an inspiring bookend briefing (a solicited entry!) of the Space Shuttle program, having just completed its last flight.

The Awards Banquet was chaired by Art "Turbo" Tomassetti, who provided his own show courtesy of TURBOtainment, a hilarious stand-up act complete with a prop-box full of hats and a brain full of great stories. The Awards Master of Ceremonies was Ed Schneider, who provided his usual professional and entertaining show-host touch. Special mention needs to be made at this point of the technology changes we incorporated this year in the Audio Visual area as a result of last year's critiques. Beginning with the San Diego Symposium, Claude Pasquis began to incorporate some new equipment into the technical sessions and the improvements afforded by this new technology were immediately evident. By the time we hit the S&B in September, Claude had worked out almost all the bugs and the quality of the audio-visual part of the technical sessions as well as the banquet was a giant step ahead of previous years.

We achieved an exceptional value-added to the Symposium this year on Friday night. Along with the much-improved menu, food quality, and seating, we also received from Disney a large collection of fast-passes to numerous rides in the park as well as park access from 1700 until closing. The Friday night reception and time in the park were great family highlights.

My experience as General Chairman this year was made particularly easy by the work and dedication of a talented team. From the day of our very first planning meeting, it was clear to me the 55th Symposium and Banquet was going to be a landmark event and one of the more memorable events in S&B history. Kudos to the great work and dedication of this team and our stalwart SETP staff for producing such an entertaining and informative Symposium.

Brett "Hollywood" Vance

## NEW MEMBER RECEPTION

The New Member Reception in the past has been on Wednesday afternoon from 1700-1830 prior to the start of the Welcome Reception for all members. It was a gathering of the eagles to welcome the newest eagles aboard to SETP. It was a gathering of some of SETP's historical members who made aerospace history and continue to participate and make a valuable contribution to SETP activities. We had three categories of war stories and aeronautical feats that were expanded during the champagne event which involved facilitators, historial and charter members. Our facilitators included J.B. Brown, Lynn Hanks, Roy Martin, Rogers Smith, Ed Schneidner, Dick Reynolds, Ricardo Traven, John Fergione, Brett Vance and Jimmy Doolittle III. The Historical members were Jesse Jacobs, Bob Gilliland, Harry Andonian, Gene Deatrick, Bob Cardenas, Bob Harper and Bob Crippen. The charter member each year was George Cooper. Each year we had a champagne toast to the new members to welcome them aboard, The toastmaster was always a historian who was a part of history themselves. We were honored to have as our past toastmasters, Bob Crippen, Bob Gilliland and Bob Harper. The SETP President presented the New Members a complimentary bottle of champagne on behalf of SETP and encouraged them to participate in the activities of the Society.

C. W. Bill Connor, PhD



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**LUNCHEON** 

Friday's Luncheon proved an extremely popular event, and not just because of the chicken! The Luncheon speaker was Mr George Whitesides, Chief Executive Officer of Virgin Galactic, who enthralled all of us with tales of future commercial space endeavour. Mr Whitesides opened his address with the question, "if money and safety were not considerations, raise your hand [if you would take a trip into space]." Every hand in the room went up — "that's my kind of crowd!" said George.

Mr Whitesides proceeded to lay out a vision for the future of access to space which all recognised as both extraordinary and imminent. George talked of an inflexion point in history as we transition from the old model of space access to one in which just about anybody who has the desire to travel to space can do so.

Mr Whitesides' modesty was also evident despite great achievement already in his life, and his candid presentation was an invaluable complement to the Symposium's technical sessions."

Justin Paines
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George Whitesides, CEO, Virgin Galactic



Students from local high schools attended the Friday sessions and luncheon

## **FRIDAY NIGNT RECEPTION**

The Friday Night Reception in Disneyland park allowed members and guest to gather for dinner and socializing, followed by free use of all the Disneyland attractions.



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## **BANQUET**

The 55th Awards Banquet was Chaired by Art Tomassetti (AF), with Ed Schneider (F) as the Master of Ceremonies.







Ed Schneider (F)

The 55th Symposium Banquet was a well attended successful event where we continued some long standing traditions and had some new and unique events. Once again the induction of our new Fellows and the awards ceremony was led by our Master of Ceremonies, Mr. Ed Schneider. Charter Member George Cooper donated some of his famous Test Pilot Red wine for an auction that raised \$5,520 for the Scholarship Foundation. In celebration of the Centennial of Naval Aviation the audience was provided several short video vignettes highlighting some nostalgic looks at the past 100 years and the development of Naval Aviation during those decades. This year the audience was exposed to Turbotainment, which included, amongst other things, a whimsical review of symposium lessons learned. These events take a tremendous amount of work by the SETP staff, Disney, our AV team and everyone who contributes to preparation and execution of the event. So, on behalf of your Banquet Chairman, many thanks and "Hats Off" to everyone who made this year's banquet another successful event.

Art "Turbo" Tomassetti





(L to R) Richard Shock and President Billie Flynn

Friend of the Society Award



(L to R) Norman E. Howell, President Billie Flynn and Mark A. Mitchell

Herman R. Salmon Technical Publications Award (Sponsored by Symbolic Displays)

"Flight Test of the Boeing 737 Airborne Early Warning and Control Countermeasures Dispense Envelope"

> Mark A. Mitchell (M), Boeing Norman E. Howell (AF), Boeing



(L to R) Billie Flynn, Simon Seymour-Dale, Justin Paines

Ray E. Tenhoff Award (Sponsored by Empire Test Pilots School)

"Nimrod MRA4 Programme Lessons Learned - A Test Pilot Perspective"

SqnLdr Simon Seymour-Dale, RAF (M)



(L to R) Billie Flynn, Charles Rudolf, Tom Roberts, Mark Moya

Tony LeVier Flight Test Safety Award (Sponsored by Gentex Corporation)

Thomas E. Roberts Naval Test Wing Atlantic

## **2011 SETP FELLOWS**



Gerald M. Baker
Mr. Baker was unable to attend Banquet. Mr. Jim Richmond accepted on his behalf.



Michael H. Carriker



Michael Collins



Albert H. Crews



LtCol Robert Hierl, GAF



Geri Kraehenbuhl



George J. Marrett



Randall L. Neville



Lyle H. Schaefer



Daniel Vanderhorst

## **2011 SETP FELLOWS**



# JAMES H. DOOLITTLE AWARD



(Lto R) Billie Flynn, Dennis O'Donoghue, award winner Joseph E. Sweeney and James H. Doolittle,

James H. Doolittle Award (Sponsored by The Boeing Company)

Joe Sweeney (F) was appointed the first company-wide Director of Flight Operations for Lockheed Martin Aeronautics in 2001. Since then he has steadily executed his vision to build a more efficient, cost effective and safe flight test organization.

His U.S. and worldwide base team has succeeded in flight testing and entering into production many major programs including the C-130J, F-22 and F-35, and in accomplishing many airframe and avionics upgrades on other aircraft.

The success of these programs was due to Joe's hands on involvement in the safety process, establishment of a solid flight test rigor and his efforts to consolidate and re-organize. Joe incorporated the operations and test organizations from all three Lockheed Martin sites under one directorate, creating a more cost effective and responsive organization and a path for implementing a common set of operating and flight test procedures.

Joe led the effort to acquire a B-737 aircraft and then launched plans to modify it with F-35 Sensors and computer systems. This new cooperative avionics test bed has extensive modifications, which require flight testing and qualifications for an experimental air worthiness certificate. Joe coordinated this effort with the Federal Aviation Administration. He then established and managed the procedures to integrate flight test and laboratory requirements. Today, the CATB is a valued resource to develop hardware and software for the F-35 program.

Joe is an SETP Fellow with over 5,000 hours in numerous aircraft types. His most notable flying accomplishments include Director for the Navy Op Eval of the F/A-18 Hornet; project pilot for F-16 multi-axis thrust vectoring demonstrator aircraft, performance of the F-16 divert-less supersonic inlet demonstration, and first flight of, and lead test pilot for the X-35C. Joe has truly distinguished himself with an exceptional 40 year career in aviation as an engineer, technical manager and test pilot.

## IVEN C. KINCHELOE AWARD



(Lto R) Billie Flynn, Jeannine Kincheloe, Iven C. Kincheloe, III, award winner Kevin L. Bredenbeck

Iven C. Kincheloe Award (Sponsored by Lockheed Martin Corporation)

Kevin Bredenbeck (M) is the Director of Flight Operations and Chief Test Pilot for Sikorsky Aircraft. He is also the X2 program Chief Pilot.

The X2 technology demonstrator incorporates a coaxial rigid rotor system, a pusher propeller and a full fly-by-wire control system to double typical helicopter cruise speeds to 250 knots, while maintaining the normal attributes of conventional helicopters.

Kevin flew the X2 twenty times, expanding the level flight envelope to 253 knots (TAS) and significantly exceeding the current speed record for helicopters in the X2's weight class. During the record setting flight, Kevin also piloted the aircraft to 263 knots in a shallow dive.

He has been the X2 project pilot from inception and has been the primary contributor to the aircraft's cockpit and control system designs. Kevin has also provided numerous other contributions to the project test team throughout the conceptualization, detail design, build and test phases of the program.

Kevin was the lead in developing takeoff and approach profiles that minimized forward control requirements due to the rotor wake causing a significant nose up pitching moment.

And during envelope expansion, as forward speed increased above 150 knots, pilot workload also increased due to reduced aircraft longitudinal static stability. Even though pitch instability near 180 knots caused precise data acquisition to become very demanding, Kevin nonetheless collected data for optimization of both the physical tail and the structure of the stability augmentation system. These two changes dramatically improved the pitch handling qualities of the aircraft such that subsequent flights above 180 knots were accomplished with low workload and a stable pitch axis. These improvements were vital factors in achieving the ultimate record airspeed.

Kevin's dedication, technical knowledge and superior piloting skills were major contributions resulting in the X2 team winning the Collier trophy for 2010.

The success of the X2 exemplifies the outstanding professional accomplishment of Mr. Bredenbeck in experimental flight test and has earned him the 2011 Iven C. Kincheloe Award.

# 2011/2012 SETP PRESIDENT



2011/2012 SETP President Steve "Hooter" Rainey (AF) accepts the "Symbol of Control" from 2010/2011 SETP President William A. "Billie" Flynn (F)



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# EUROPEAN FLIGHT TEST SAFETY WORKSHOP

8-11 November 2011 Salzburg

The beautiful, city of Salzburg is not only the home of European classical music and the home of Red Bull Racing, but in November 2011, it was also home to the annual gathering of European test pilots at the European Flight Test Safety Workshop 2011. Against the themed backdrop of "Flight Test Demonstration of Prototype Aircraft," forty experimental test pilots and flight test engineers from as far afield as Japan, the USA and South Africa, joined their European colleagues representing major and minor aircraft manufacturers, in bringing safety lessons learned to the fraternity with the view to preventing accidents during flight test demonstration flying.

The purpose of the three-day workshop was to develop benchmarked, best practice procedures, processes, checklists and to consider manoeuvre design to assist current and aspirant flight test demonstration pilots. Presentations by highly experienced flight test demonstration pilots, were real and relevant. More than ever though, it was apparent that adequate regulatory oversight existed, yet accident rates during display flying are not improving - far from it, they're actually getting worse.

"High Performance Airshows vs. Product Demonstrations – and the Fickleness of Knowing the Difference" was the topic reviewed by Boeing F-18 Super Hornet display pilot Ricardo Traven, while Cassidian's Eurofighter display pilot, Chris Worning, complemented the high performance jet deliberations, discussing "Displaying the Typhoon - Lessons Learned."

Ploughing back many, many years of experience, Patrick Experton, Mirage III, Mirage 2000 and Rafael test pilot, presented "Dassault's View" on flight test demonstration flying, particularly the role of the flight test team and the monitoring of performance data during the actual display. The former Dornier chief test pilot, Dieter Thomas, dealt with the "Tricks of the Trade" gathered over more than 35 years of demonstrating new designs. Andrew Warner, Eurocopter's chief test pilot, brought another dimension to the deliberations, discussing the idiosyncrasies of demonstrating helicopters in his presentation on "Rotorcraft Displays;" considering the high agility and manoeuvring margins of current helicopters, it is imperative that the flight test experience gained, particularly in terms of techniques and structural loads generated by such demonstrations, be passed on to helicopter pilots and the airshow community at large.

In what must be regarded as a first, the chief test pilots of Airbus and Boeing, Terry Lutz and Dave Carbaugh – combined their presentation to share the lessons of demonstrating modern 'big jets' in their presentation, "Displaying Transport Category Aircraft." When it comes to flight test demonstration safety, there can be no petty jealousies or competitive arrogance, all survival and safety techniques and skills must be shared by the entire display community.

Lockheed Martin test pilot Wayne Roberts spoke in detail about the quintessential differences in "Displaying Fast Jets and Transports in Military Operations" while Tore Reimers asked, with respect to Shakespeare: "To Display or Not To Display – That is the Question" in which he addressed the fatal accident of Grob's chief test pilot, Gerard Guillaumaud. The Grob G180 SPn suffered a flutter induced tailplane (elevators and left horizontal stabilizer) separation and crashed during a demonstration flight at the factory at Mindelheim-Mattsies Airport on 29 November 2006.

Delegates were also invited to share their lessons learned during demonstration flying 94 July - December 2011

and in this case, flight test engineer Christoph Schlettig gave an in depth description of the handling and performance challenges they faced in their flight test demonstration of the "Solar Impulse Display" at Le Bourget airshow. The Solar Impulse is the latest aerospace engineering innovation designed for ubiquitous twenty-four hours surveillance using solar energy; a wingspan of 63 metres, a takeoff mass of 1600 kg powered by four 10 HP, scooter engines – visionary thinking but presenting a whole new dimension to aircraft handling challenges.

Des Barker from South Africa's Council for Scientific and Industrial Research (CSIR) provided the keynote introduction to the workshop by providing 'A Safety Perspective on Test Pilots in Demonstration Flying" which included a look into the differences in low level demonstration philosophies between test pilots and non test pilots, the suggested selection criteria for flight test demonstration pilots and also proposed the "10 Rules for Display Flying Survival."

Question raised. Is there a difference in the philosophy of low level demonstrations between test pilots and airshow pilots? Apparently yes. Statistically, it would appear that test pilots were involved in less than 10% of all air exhibition accidents over the past 103 years. Test pilots were the forefathers of airshows/display flying but separated from their non-test pilot brethren many years ago, for obvious reasons in the difference in objectives between flight test demonstrations and airshows.

What is certain is that it has become essential for test pilots to share their experiences and philosophies on risk management and sequence development with non-test pilots. Just maybe, a more scientific/systems engineering orientated approach could provide display pilots with a more holistic understanding of the energy management of each manoeuvre and also their risk budget for each manoeuvre. The entire display community needs to 'compare notes' in the way they go about risk management and display sequence planning, it may just be the remedy to ameliorate the unacceptably high loss rate currently on the world's airshow circuit.

## Dr. Dieter Reisinger (M)



The European Flight Test Safety Award was founded by the fiancée of test pilot Gerard Guillaumaud, Ms Heidi Biermeier, after the fatal flight test demo accident of the Grob SPn. Recipients must be lindividuals who have made significant contributions in the area of safety within flight testing.



Lockheed F-16 chief test pilot Billie Flynn (recipient 2010), presented the SETP European Flight Test Safety Award 2011 to retired Mai Gen Barker of the CSIR. Flanked by Ms Heidi Biermeir, Aviation Management and Communication, the award founder, and Cessna chief test pilot, Maurice Girard, Chariman of the Flight Test Safety Committee. (Dr Dieter Reisinger)



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## REQUEST FOR NOMINEES FOR KINCHELOE AND DOOLITTLE AWARDS

The Board of Directors of The Society of Experimental Test Pilots has issued a call for nominations for the Iven C. Kincheloe Award and the J. H. Doolittle Award. Any member or person who has knowledge of a candidate's accomplishments may submit a nomination(s) for either or both of these awards. To help in determining appropriate nominees, information about each award is given below.

### NOMINATIONS FOR KINCHELOE AND DOOLITTLE AWARDS MUST:

☐ Be presented in writing not later than 12 August 2012

Contain pertinent information concerning the candidate's work.
Be submitted to the SETP Board of Directors, P.O. Box 986, Lancaster, CA 93584

Selection will be announced at the 56th Awards Banquet on 29 September 2012 at The Grand Californian Hotel, Anaheim, California.

The presentations of these Awards are highlights of the Banquet. Each recipient will receive a small replica of the respective award, while the perpetual trophies remain on display at SETP Headquarters.

### THE IVEN C. KINCHELOE AWARD

(Sponsored by Lockheed Martin) - In 1958, The Society of Experimental Test Pilots established the Iven C. Kincheloe Award in memory of the late Captain Iven C. Kincheloe, USAF. The purpose of the Kincheloe Award is to recognize outstanding professional accomplishment in the conduct of flight-testing.

#### KINCHELOE SELECTION CRITERIA

- 1. Recipient must be a living member of the Society.
- 2. The accomplishment or at least a significant phase must have occurred during the past year (1 July to 1 July).
- 3. The accomplishment must involve actual flight-testing conducted by the individual and represent outstanding contribution to an aerospace flight program while acting as a test pilot thereon.

### THE J. H. DOOLITTLE AWARD

(Sponsored by Boeing) - was established to honor outstanding accomplishment in technical management or engineering aspects of aerospace technology. It was presented for the first time in 1966.

### DOOLITTLE SELECTION CRITERIA

- Recipient must be a living member of the Society.
- A significant phase of his accomplishment must have occurred while a member 2. of the Society.
- 3. The accomplishment clearly must be in technical management or engineering aspects of aerospace technology.

Please submit the nominations in the following format, typed individually for each candidate submitted not later than 12 August 2012:

Name of Award:

Name and Address of Nominee:

NOTABLE FOR: (NOTE- A minimum of 50 words describing why the nominee should be considered is requested. WITHOUT THIS SUBSTANTIATING DATA, the Committee will not be able to consider the nomination.)

Submitted by:

PLEASE SUBMIT TO:

The Society of Experimental Test Pilots
Post Office Box 986
Lancaster, California 93584-0986
Email: setp@setp.org

### CALL FOR HONORARY FELLOW NOMINATIONS

Nominations of appropriate individuals for consideration as Honorary Fellows in The Society of Experimental Test Pilots will be reviewed by the Fellows Coordinating Committee at its annual meeting. The recommendations will be presented to the SETP Board of Directors for final approval.

We feel your contribution will assist in obtaining the most select group of candidates from which to elect these former test pilots qualified to receive one of the highest honors extended by the Society. In order for the members of the Committee to give proper consideration to all the details pertaining to choosing this individual, please keep in mind that they might be unaware of the impressive background experience of the nominee. This information should be submitted in the appropriate format (below) to reach SETP Headquarters not later than 16 March 2012. Please be prepared to support your nominee by collecting pictures, films, etc. for the presentation of the award in September.

Current stipulations established by the SETP Constitution in making these selections are listed below.

# \* \* \* \* SETP CONSTITUTION \* \* \* \* ARTICLE III

#### SECTION 3. HONORARY FELLOW

An Honorary Fellow shall have achieved particular distinction in the aerospace field and shall have been engaged as an experimental test pilot at some time during his career.

Nomination of an eligible candidate for Honorary Fellow may be volunteered in writing to the Fellows Coordinating Committee by any member of the Society. Such a nomination shall be accompanied by the appropriate information and documentation that will enable the Chairman of the Coordinating Committee to verify the candidate's history and eligibility for the distinction of Honorary Fellow prior to the annual meeting of the Committee.

Selection of a candidate to the grade of Honorary Fellow shall be by three-fourths or more affirmative votes of those Fellows present at the annual meeting of the Fellows Coordinating Committee. Selection(s) of nominee(s) shall be presented to the Board of Directors for final approval.

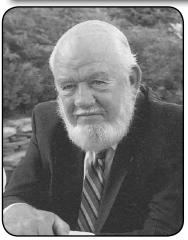
### \* \* \* \* HONORARY FELLOW NOMINEE \* \* \* \*

I propose the following person as a suitable candidate for Honorary Fellowship in the Society in conformance with the qualifications stipulated in the SETP Constitution. NAME AND ADDRESS OF THE NOMINEE: NOTABLE FOR: (Substantiating background, particularly flight test work, of 50 words or more must be submitted. If you feel that articles, clippings, and photographs will enhance your nomination, please feel free to include them) SUBMITTED BY: \_\_\_\_\_

DATE:

Please email to SETP@SETP.org

# **LAST FLIGHTS**



**Alan D. Ashley (AF),** was born on 14 May 1933 in Gloversville, New York, the son of Edwin and Opal (Shank) Ashley. He passed away at his home on 9 June 2011.

Alan served in the U.S. Marine Corps from 1955–1958, at which time he joined Kaman Aerospace Corp. as an experimental test pilot. He performed developmental flight testing of the HH43B and UH-2A helicopters, and production flight testing of the HOK, HUK, H043A and H-43A/B. Alan performed at least 15 first flights and "end point" investigations on unproven major rotor/rotor control system variations on UH-2 series helicopters. In addition, he conducted flight training programs and service liaison for the Army, Air Force and Navy. He later became Chief Test Pilot for Kaman Aerospace, and was involved in almost every flight test program, such as the Navy's HUK-1 and HU2K-1, the Air Force SH-26 and the K-MAX.

Alan joined SETP in 1965 and was also affiliated with the American Legion, Antique Airplane Association and the American Helicopter Society. He was an avid woodworker and an antique car tinkerer. He was predeceased by one brother, Jerome Ashley, and one sister, Mary Parnitzke. Survivors include his wife, Carol (Fulkerson) Ashley, of Gilford; two sons, Drew Ashley and his wife, Jerry, of West Suffield, CT and Dean Ashley of West Suffield, CT, one daughter, Allison Bergstrom, and her husband, David, of Anaheim, CA and two grandchildren, Dylan Bergstrom and Ashley Bergstrom, both of Anaheim, CA.



**Joel Robert (Bob) Baker (F)**, was born on 19 March 1920 and passed away on 14 November 2011 at the age of 91. He was a charter member of SETP and became a Fellow at the first annual banquet in 1957.

Bob received a BS in Aeronautical Engineering from Rensselaer Polytechnic Institute in 1941. He received his commercial pilot certificate with an instructor's rating in 1942 and went to work as a flight instructor. He then joined Curtiss Wright Airplane Co. as a test pilot where he flew the P40L, P40N, XP40Q, XP60E, P47G, C46 and PB5YA.

In 1945 Bob moved to NACA (now NASA) as a research test pilot at Langley Field. He flew the FM2 (F4F), F6F, XF8F, SB2C, F3A (F4U), JRF, BTD, SC-1, P47D, P47N,

XP51, P51B/D/H, P63, P80, B17, B24, B29, A26, C45, C47, C54, UC78 and YR4B helicopter. He received his first caterpillar pin after he was forced to bail out of a burning P47N when the propeller governor failed during a high speed propeller data run.

In 1947 Baker joined Chance Vought Aircraft as the Project Pilot on the XF4U5 Corsair. This was the first Corsair to demonstrate 506 mph. He then took over the XF6U program at Patuxent River. He made the first flight on the first production F6U1 Pirate. He also made the first flight

on the XF7U Cutlass and became Chief Test Pilot. Bob was one of the original pioneers in the development test flying of afterburners and irreversible hydraulic control systems with artificial feel.

Bob joined North American Aviation in 1949. He received his second caterpillar pin when the 16th spin in the F100F spin demonstration went into a flat spin. He ejected on the 20th turn before the aircraft spun into the ground. In 1956 he made the first flight in the YF107 which was a Mach 2.0+ aircraft. While at North American, he graduated from the B47 Command Pilot School at McConnell AFT and flew B52's with Boeing.

In 1960, Bob joined Garrett Corporation in Sales. After 15 months, he returned to flight test with Boeing to fly the 707 and 720 and certified in the 727. In 1964 he returned to Garrett Corporation in their new flight test section. For the next 23 years he flew turboprop and turboprop test beds in Phoenix, Arizona.

Baker also made the first flights in a converted Beechcraft C45 at Volpar in Van Nuys, California.

During Bob's flying career of 45 years, he flew 14,000 hours in 120 different aircraft and made the first flight in six different aircraft prototypes. During 24 years with the Garrett Corporation, he was at times on loan to 15 aircraft manufacturers around the world as a test pilot. He entered over 100 different countries as pilot-in-command and in 1974 went around the world five times.

After retirement, Bob flew and instructed in sailplanes in Phoenix and spent summers in Madrid with his wife, Carmen.



Maj Gen Josef Bernecker, AAF (Ret) (AF), was born on 17 September 1939 in Vienna, Austria and passed away on 24 December 2011.

In 1961 Josef graduated from Militärakademie WR. Neustadt and from Landesverteidigungsakademie Wien in 1972. In 1965 he was chosen as one of two operational pilots to become the first test and evaluation pilots for future military air materiel of the Austrian Air Force. His first training was done the hard way – they sent him to Chester to participate in an inverted spin test program for the Vampires (DH-115). He then did comparison testing for the Saab J-29 "Flying Barrell" successor between the F-5A. Draken, Skyhawk and Mirage III. Work on the Saab 105 started as a replacement for the aging Fouga Magister Trainers. Josef then took over the (then) Systems Planning, Evaluation and Test Division of the Air

Staff. Over the next ten years his personal test activities included weapon system integration on the Saab-105, Project Pilot for Pilatus Turbo Porter, weapon system integration on the Pilatus trainer PC-7. He then became project leader for the implementation of the newly acquired Saab Draken into the Air Force.

Josef was designated as Chief of the Air Staff which left little time for test flying. The E&T Division was one of six units in his staff and he took every chance to be back on board new aircraft which was the category demonstration or evaluation for Generals. These aircraft included the Mirage 2000-5, F-16, F-18, F-104, C-130, C-235, C-295, L-39, MiG-AT and PC-12. Josef retired in 2002.

Josef joined the Society in 1975 and was serving as the SETP Vice President of Austria. He is survived by his wife, Elisabeth Bernecker.



Glenn H. Brink (LM), a pioneer of commercial air transportation and avid sailor, died peacefully and joyfully Christmas morning 2011, at his daughter's home in Southbury, CT. Prior to moving to Southbury, he lived for more than 50 years in Manhasset, NY. He was a sweet and loving husband, father and friend, and a gentleman, always. He was 94.

Born in Buffalo, OK, April 8, 1917, to Hazel Blanche Brownrigg and Earl Barrett Brink, he lived a full and accomplished life. A 1939 graduate of the University of Michigan College of (Aeronautical) Engineering, where he was president of The Flying Club and treasurer of the National Intercollegiate Flying Club, he spent the next 38 years at American Airlines. He was Director of Aircraft Development/Flight Engineering, Chief Test Pilot and the youngest commercial airline captain in the country at the age of 25, earning

the "Million Miler Award" at age 33. He retired in 1977 and continued work as an aviation consultant.

During the 1940s, under contract to General Electric, he flew its then experimental plane through a series of tests which developed the cabin pressurization system that was put in the B-29 Superfortress bombers and that are now used in all modern planes. In a related test conducted in a Douglas B-23, he simulated a drop of 8,000 feet in four seconds, or a pressure change of 22.72 miles per minute, at 25,000 feet over New York. In 1943, when conducting tests at La Guardia Field, NY, the weather conditions were too warm; he immediately flew the four-engine C-54 to the Arctic Circle, returning a week later with successful test results. In 1948, he earned American Airlines' highest award, the "Award of Merit" for "astute application of engineering analysis in establishing promptly the cause of two Douglass DC-6 fires." Consulting for Curtiss-Wright, he was instrumental in the development and design of the modern day flight simulator.

Later, in the 1950s, his test work to determine take-off problems with the DC-6s "would prove to be a milestone" in leading aircraft designers and the then-Civil Aeronautics Authority (now the FAA) to take into account fully the effect of outdoor temperature on allowable gross weights in the calculation of takeoff performance, according to a 1993 Air & Space article. In 1953 he was named by AA's then-President C.R. Smith a commanding member of "The Order of Flying Firsters," an organization created to recognize "pioneering in air transportation," for flying the first transcontinental nonstop flight on the DC-7, from New York to Los Angeles, about which he was interviewed by Walter Cronkite. He also conducted the acceptance tests for AA on the first new airplanes – the DC-6s, Convairs and Stratocruisers; and oversaw the development and flight tests of the Convair 990 Astrojets and the Boeing 727s, while at the same time planning for the future of the supersonic airliners.

In the 1960s, he served as an American Airlines representative to the Supersonic Transport Advisory Group established in 1961 by the Kennedy administration to investigate the viability of commercial airlines supersonic transport, a proposal later abandoned in favor of 'jumbo jets' like the Boeing 747, the last plane he captained prior to retirement. In 1963, he earned his "Mach Deuce" rating in the Royal Order of Starfighters when he flew a Lockheed Starfighter F-104G at twice the speed of sound at Edwards Air Force Base. The F-104 was one of the supersonic planes that then held the world records for speed, altitude and time to climb – simultaneously. He also flew the DC-2, DC-3, DC-4, CV-240, DC-6, DC-7, L-188, B-707, CV-990, B-727, BAC 1-11, B-747, and the DC-10. During WWII, he flew B-24 bombers under contract to the War Department for the North Atlantic Operations of the Air Transport Command, a select few AA pilots who pioneered an all-weather 'airline' via Presque Isle, ME, to Labrador, Iceland and Greenland, about 102 July - December 2011

which his friend, author and aviator Ernest K. Gann wrote in "A Hostage to Fortune." The ATC transported personnel and supplies in support of the war effort.

He took his first flight at the age of two in his father's barnstormer, a Curtiss JN4 "Jenny," in the Oklahoma corn fields, soloed in a Great Lakes aircraft at 16 in 1933, and earned his private pilot's license in 1934. For recreation, he participated in many aerobatic exhibitions and air races. Dubbed "The Monocoupe Kid," by Detroit News Aviation Reporter John S. Hammond II, he flew his first plane, a Monocoupe, in the 1936 Ruth Chatterton Sportsman Pilots Air Derby from Cleveland, OH, to Los Angeles. The race was held annually in conjunction with the National Air Races, where he also flew demonstrations. A captain of the skies and seas, he was an avid sailor and a member for nearly 72 years of Manhasset Bay Yacht Club, and the Aspatuck and Quantuck yacht clubs, all on Long Island, NY. He sailed and raced his Star boat "Bandersnatch," his Manhasset Bay One Design "At Last," and his Cal 36 "Windfall" throughout the Atlantic seas, including a crossing from New York to Yugoslavia aboard the boat "Ksenija." He played tennis regularly, including more recently at his former Southbury, CT, residence at the Heritage Village 40th Anniversary Celebration's "Nonagenarian Tennis Match" when he was 91. He also skied into his eighties.

He was a life member of the Grey Eagles, an organization of retired American Airlines pilots, and the Society of Experimental Test Pilots. His name is inscribed on the National Air and Space Museum's Aviation and Space Exploration Wall of Honor in Washington, DC.

He was predeceased in 2004 by his wife, Ann Dolores F. Rapp, to whom he was married August 16, 1942, at Our Lady Queen of Martyrs Church, Forest Hills, NY; a brother, John E.; a brother-in-law, L.W. "Scoot" Llewellyn; and a sister-in-law, Marjorie Osborne. He is survived by a brother, Bill O., of Grosse Pointe, MI, and sister, D'Arlene Llewellyn, of Sarasota, FL; sister-in-law, Suzanne Coté Brink, St. Petersburg, FL; his five children: Nancy Ann Taylor and husband, Ron, of Seminole, AL; Glenn Hamilton and wife, Barbara Tibbetts, of Calverton, NY; Christopher Barrett and wife, Eliana Duarte, of Yonkers, NY; Patricia Ann, of Southbury, CT; and Elizabeth Ann Matthei, of Newtown, CT; six grandchildren: Christopher, Gregory, Craig, Christopher, Molly and Patrick; and three great-grandchildren.

Donations may be made to the Fisher Center for Alzheimer's Research Foundation, West 46th Street & 12th Ave., NYC, NY 10036, or www.ALZinfo.org.



CAPT Robert A. Clarke, USN (Ret) (M), was born on 13 June 1920 and passed away on 12 October 2011. He was the eldest of three sons with siblings James W. Clarke and Thomas C. Clarke. He grew up in Rockville Centre, Long Island, New York and attended public schools there, moving on to Colgate University, Class of 1942.

Robert joined the US Navy in 1941 as an aviation cadet. His flight training was done at Floyd Bennet Field, Brooklyn, NY, NAS Pensacola, Pensacola, FL and NAS Opa Locka, Miami, FL. He was designated a US Naval Aviator in 1942.

During WWII, Robert served with Bombing Nine (VB-9) aboard the USS Essex (CV-9), Marcus Island, Wake Island, Midway Island, Gilbert Islands,

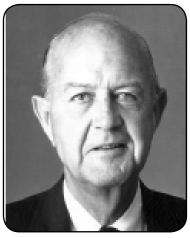
Marshall Islands, Rabaul, Truk Island and Marianas Islands as well as Nightfighting Forty-Three (VFN-43 and VFN-53) aboard the USS Saratoga (CV-2), USS Kula Gulf

(CVE) in Okinawa and Iwo Jima.

After the war, CAPT Clarke graduated Class #1, US Naval Test Pilot School, Patuxent River, MD, and graduated Course #9, Empire Test Pilot School, VF-71 - first Atlantic Fleet Jet squadron in 1950. He was the Commanding Officer, VF-102 aboard USS Tarawa (CV-40) and Commanding Officer, US Navy Flight Exhibition Team - The Blue Angels. He developed and introduced the 4-plane diamond formation (now the Blue Angels' trademark). He was also a significant contributor to development and testing of the angled carrier deck, steam catapault, and a wide variety of US Naval aircraft. He is listed in the US Naval Aviation History archives as 91st among Early Naval Aviators to fly all-jet aircraft. He completed three tours as a US Naval Test Pilot at Naval Air Test Center, Patuxent River, MD. This included first Navy evaluations of XF4D-1, XF3H-1, F7U-3.

After retiring as Captain, USN in 1965, Robert completed 25 years of service with The Boeing Company. He retired to Oyster Bay, Australia.

Capt. Clark is survived by his brother Thomas Clarke, son Robert Clarke, daughter Thorne Clarke, and wife Vinci.



**J. Lynn Helms (M)**, 86, of Westport, CT passed away quietly on December 11<sup>th</sup> with his family around him.

Born in 1925 in DeQueen, Arkansas, J. Lynn Helms was a retired U.S. Marine Corps officer, former President of Piper Aircraft Corp. and is most recognized for the years in which he served as Administrator of the Federal Aviation Administration, as an appointee of President Ronald Reagan.

In 1947, while serving in the Marines, he met and married Lorraine Rose Bisgard of Denver, Colorado. The family moved to Westport in 1969 when Mr. Helms became President of Norden Technologies division of United Aircraft Corp. in Norwalk.

During his tenure as FAA Administrator Helms originated and oversaw development of the 1982 National Airspace System (NAS) Plan; He headed the US delegation to the United Nations emergency session following the Soviet Union's shooting down of Korean Air Flight 007 and played a key role in the August 3, 1981 Air traffic Control Strike.

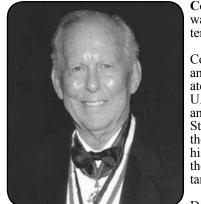
Helms began his aviation career when he joined the U.S. Navy Aviation Cadet training program while at the University of Oklahoma, early in 1942. On completion of the program he was commissioned as a Second Lieutenant, U.S. Marine Corps, remaining in the service as a regular officer after the end of WW-II. Subsequent service included postings to Japan, China, Korea, various aircraft carriers and other Military Assignments. He became a U.S. Navy test pilot on graduation from the U.S. Navy Test Pilot School, test flying the earliest American jet aircraft. He was awarded the U.S. Marine Corps Air Medal and the USAF Air Medal with Oak Leaf Cluster for Combat and Exceptional Service during the Korean War. He was the first man to fly 1000 miles an hour, accomplishing this in the Navy's F8U Crusader on June 24, 1955. He subsequently retired from the Marine Corps

with the rank of Lt. Col.

He was an active yachtsman, regularly sailing the family's Rhodes sloop "Aeolus" on Long Island sound; and remained an active pilot all of his life. In his later years, his favorite pastime was cheering on his grandchildren on the sports fields.

He is survived by his wife, Lorraine Bisgard Helms of Westport; his daughter, Loralyn Helms of West River, MD; his daughter Carole Helms Reichhelm and her husband George Reichhelm, of Westport; his son Zackary Helms and his wife Katharina Rourke Helms of Wilton; his grandchildren, Chelsea Maruia Helms, Clayton Jon Helms and Tegan Rourke Helms, all of Wilton, CT; and his brother, Robert Helms and his wife Hazel, of DeQueen Arkansas. He was predeceased by his oldest son, Jon L. Helms II.

In lieu of flowers, donations may be made to the Wounded Warrior Project; www. woundedwarriorproject.org. Condolences for the family may be left on line at www. hardingfuneral.com.



Col Robert E. Howard, Jr., USMC (Ret) (AM), was born on 15 June 1928 and passed away on 21 September 2011 at the age of 83.

Col. Howard was born in Tulsa, Oklahoma, in 1928 and later moved to Oklahoma City, where he graduated from Central High School. He enlisted in the U.S. Navy, was selected for Aviation Navy ROTC and chose to attend Oklahoma A&M, now Oklahoma State University. In 1949 he became a midshipman in the Navy and commenced flight training. He received his wings and commission as a Second Lieutenant in the U.S. Marine Corps and began his 29 years of military service.

During the Korean War, he flew 105 combat missions with VMF-122, Marine Air Group-13; and during the Vietnam War as Commanding Officer, VMFA-122, Marine Corps Air Group-13, he flew 330 combat missions. His awards and decorations include the Legion of Merit with Combat V, two Distinguished Flying Crosses, seven Air Medals, 24 Strike/Flight Air Medals and the Navy Commendation Medal

Robert participated in the technological revolution in flight operations that followed World War II. He was a test pilot at Naval Ordnance Test Station, China Lake, California, from 1957 to 1960 as part of the development of the Sidewinder missile. He earned master's degrees from the U.S. Naval Postgraduate School in Ft. McNair and National War College in Washington, D.C.

After retirement Robert served as President of the Board of Directors of Meals-on-Wheels in Vista, California. He was selected for membership in the elite Early & Pioneer Naval Aviators Association (the "Golden Eagles") and in 2010 was inducted into the Oklahoma Military Hall of Fame. He was active in the Episcopal Church and served in a variety of capacities and held several offices.

Survivors include his wife, Rodella (Peg) Howard; a brother, Monty Howard and wife, June, of Oklahoma City; three daughters, Lisa Buchanan, Carolyn Coombs and Mary Hollas; a son, Monty Howard; his aunt, Helen Helt of Stillwater; grandchildren, Shannon Vaughn, Nick Vaughn and wife April, Dallas Coombs, Calin Hollas, and Carly Hollas; and great-grandchildren, Samantha Mills, Wyatt Harlan, Maegan Vaughn, and Cassidy Vaughn.

The family suggests that donations be made to the Episcopal Church of the Resurrection, 13112 N. Rockwell Ave., Oklahoma City, OK 73142; or to the Disabled American Veterans, PO Box 14301, Cincinnati, OH, 45250-0301.

Interment will be at Arlington National Cemetery at a date yet to be determined.



Dalton L. "Lefty" Leftwich (M), passed away peacefully at his home in Corrales, New Mexico on January 9, 2011. LTCOL Leftwich was born in Nocona, TX on January 10, 1928. He served in the United States Marine Corps from 1946 to 1948. After attending SMU he resumed his military career in 1951, but in the United States Air Force, first as a radar officer, then as a test pilot. He subsequently earned degrees in both mechanical and electrical engineering at Oklahoma State University in 1962. He finished jet pilot training at Bryan Air Force Base in 1952 and was assigned to duty in Japan, where he trained pilots for the Japanese Air Defense Force. During this duty he became fluent in Japanese and developed a life-long interest in the Japanese culture and language. Back

stateside, he was assigned to advanced flight training, including a tour at "Top Gun" school in Nevada. During his military career, LTCOL Leftwich flew most of the Air Force fighters in service at that time.

In 1967, LTCOL Leftwich flew over 100 air strike missions over North Vietnam and was awarded the Air Force Air Medal with eighteen Oak Leaf Clusters, the Distinguished Flying Cross with two Oak Leaf Clusters, and the Silver Star with two Oak Leaf Clusters. As a result of his valor in aerial combat over the Red River in Southeast Asia, he was honored with membership in the Red River Valley Fighter Pilots Association. He retired from the Air Force in 1970 and returned to Dallas, where he served on the Dallas-Fort Worth Regional Airport Board. After his retirement from DFW Airport, he was a realtor for Ebby Halliday Realtors and an international aviation and business consultant, expanding his spoken languages to include German. He fully retired to Corrales, NM in 2003, where he could be seen taking brisk walks around the village every morning.

LTCOL Leftwich was preceded in death by his wife Jeanette and his son Lee. He is survived by his brother James M. Leftwich and sister Amy Fikes, both of Dallas, daughters Lorraine Leftwich of Corrales, NM, Elizabeth Leftwich Harvey of Coppell, TX, and Olivia Lynn Leftwich of Corrales, as well as granddaughters Drew Leftwich Bowman, Leslie Leftwich Bowman, and Audrey Harvey.

Funeral services and burial with full military honors were held at Sparkman-Hillcrest Memorial Park in Dallas, Texas on Saturday, January 15, 2011.



Reuben P. Prichard, USN (Ret) (AM), was born on 13 June 1925 and we recently learned, passed away on 7 August 2008 at the age of 83.

A native of Syracuse, New York, Reuben graduated from the U.S. Naval Academy in 1947 and married the former Jeanie Moore of Villisca, Iowa the same year. Following a tour aboard the escort carrier Siboney and flight training, he flew 120 missions in the Korean conflict and became training officer in attack aircraft for the Atlantic Fleet.

In 1955, Reuben graduated at the top of his class from the Naval Postgraduate School in Monterey, California, with a B.S. degree in aeronautical

engineering. He earned an M.S. degree from Princeton University in 1956, specializing in aircraft stability and control. He received the Outstanding Student award when graduating from the Navy Test Pilot School in 1960. Reuben won many honors, including the Distinguished Flying Cross, eight Air Medals, two Navy commendation medals, three Navy Unit commendations and 13 campaign medals.

In 1965, Reuben served as Executive Officer and a year later as Commanding Officer of VT-26, an F-11 Tiger aircraft training squadron. In 1968 he served as Executive Officer of the carrier Ticonderoga in waters off Vietnam and Korea.

Reuben was a veteran of more than 34 years as an aviator, with several thousand hours of flight experience in more than 140 types of aircraft. He served five years during two tours at the Naval Air Test Center in Patuxent River, Maryland, one tour as a test pilot and Program Manager and the second tour as Director of the Navy Test Pilot School.

Following his retirement from the Navy in 1970, Reuben joined NASA where he was Assistant Director of Safety for Aviation, then Director of Safety and Environmental Health. In 1979, Reuben joined the Department of Energy as Director of the Safety Engineering and Analysis Division.

After retiring from civil service in 1983, Reuben founded and directed R.P.X. Inc., an aviation safety consulting business.

Reuben's life was deeply rooted in his Christian faith, and all who knew him felt his love, respect and caring. Reuben was a longstanding member and an ordained elder of Lewinsville Presbyterian Church in McLean, Virginia.

Reuben is survived by five children, Paige Kennedy of Scotsburn, Nova Scotia, Polly Lehtonen of Columbia, Maryland, Reuben Prichard III of Raleigh, North Carolina, Priscilla Merrill of Northwood and Richard Prichard of McLean, Virginia, six grandchildren and one great-grandchild. His wife Jeanie preceded him in death in September 2007.

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