

Gateway News

American Institute of Aeronautics and Astronautics, St. Louis Section



April 1997

Chairman's Corner

The Section's program year runs from June through May, and as such, we have entered the time period for identifying candidates for officer and council leadership positions. Per our Section bylaws, I have asked Paul Czysz, our current vice chairman and therefore, chairman-elect for the 97-98 program year to form the nominating committee. If any member is interested in being an officer, advisor, or holding a council leadership position, please call Paul at 314/434.2188, or e-mail him at czysz@pxa.slu.edu. He'll appreciate your input. *The nominations must be returned to the council by April 1.* Ballots to the membership will follow shortly afterwards.

Mark your April calendars early for the annual student paper competition scheduled for 16-18 April at Henry VIII Motor Inn. The competition is looking for individuals willing to judge the student papers in the undergraduate and graduate level divisions. If you want to be a judge, contact Paul Czysz at the number previously listed. The Awards banquet will be on Friday evening, 18 April, and will feature a talk by internationally

renowned author and lecturer, Bill Sweetman, so circle the date and plan to attend.

Our Section will also be judging at the St. Louis Post-Dispatch sponsored Science Fair on the night of 18 April (yes, we are busy and schedules overlap). If you want to judge the science fair entries at Queeny Park, contact Dianne Chong at 314/233.8362 or Bill Bernzott at 314/234.6271. We award five \$50 prizes and invite the winners to our May Awards banquet to be recognized.

You should be proud of your Section and the opportunities it affords you and the community at large. Volunteer organizations such as the AIAA are in a difficult era due to the many demands on member's (or potential member's) time. These excellent programs, opportunities to network, support of community programs, interacting with students and developing science & technology interest come with a price tag. We need people like you to participate. If you can't take a lead role or be a member of a committee, please attend the high quality events we offer. As a minimum, say thanks to those who are making it happen in the St. Louis Section when you see them. See you next month. ■

Walt

Mach 3+ Flight Vehicles

The quest for speed has been a dream of man since the beginning of the flight era. Speed was vigorously pursued throughout World War II because of the tactical advantage it afforded in combat. The speed quest continued after the war with a series of rocket powered X-aircraft. The "sound barrier," as it was known in the 1940's, was first broken in 1947. Mach 2 flight was then exceeded in 1953, followed by Mach 3 in 1956. Next the X-15 became the first airplane to exceed Mach 4, 5, and 6 in 1961. More recently, the Pegasus rocket plane passed Mach 7 and 8 in 1990. Figure 1 illustrates this progress in the speed quest in the 15 years following the first Mach 1 flight. Early Mach 3 vehicles were rocket powered and reached their record breaking speeds after being dropped from a mother ship. The early use of a mother ship was necessary to maximize available fuel to reach the desired speed and altitude.

Fifteen vehicles were identified in this survey as being capable of flight in excess of Mach 3. Selection criteria used focused on vehicles capable of Mach 3 cruise. Thus the Space Shuttle and missiles that operate transiently past Mach 3 were not included. The selected 15 vehicles are shown in Table 1 with information on first flight, top speed, and number of flights. Of the 15 vehicles, 11 were designed in the United States, 3 in the former Soviet Union, and one in the United Kingdom. Nine were manned aircraft and 6 were unmanned. Plan views of these Mach 3+ vehicles are illustrated in Figure 2, and drawn to the same scale.

General Aircraft Notes

The first aircraft to exceed Mach 3 was the Bell X-2. Its rocket engine consumed the last of the propellant as a top speed of Mach 3.2 was reached. Unfortunately during

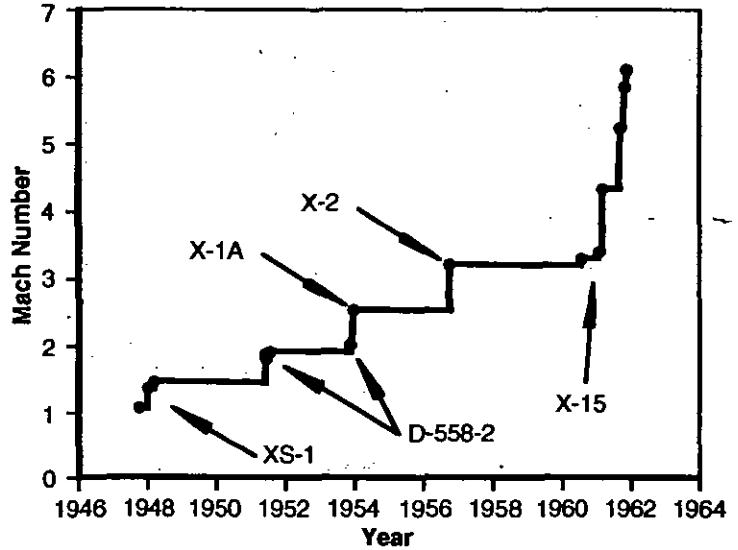


Figure 1 - Speed Growth of Rocket Powered Manned Aircraft

deceleration from the record speed, the aircraft went out of control and entered an inverted spin. Unable to recover the aircraft, the pilot ejected, but was killed when he hit the ground.

Two survey aircraft, XF-103 and XF-108, never flew; however, a significant amount of engineering had been done at the time their programs were canceled. Both were designed to operate as interceptors flying in excess of Mach 3. Likewise, the T-4 and T.188 were flown but never reached their Mach 3 design speed.

The unmanned D-21 was developed by Lockheed to provide reconnaissance over the Soviet Union. Its ramjet engine required a high speed to start; therefore, it was initially launched from the top of an SR-71. After an SR-71 launch

Table 1 - Identification of Mach 3+ Aircraft

Aircraft	First Flight Date	Design Mach Number	Highest Mach No.	Number Built	Number of Flights
Bell X-2	27 Jun 52	3.05	3.2	2	13 (a)
Boeing Bomarc	10 Sept 52	3.8		700+	
North American Navaho	6 Nov 56	3.25			11
Larochkin Burya	Dec 58		3.2		18
North American X-15	8 Jun 59	7.4		3	
Republic XF-103	Not Flown	3.7	NA	0	0
Beech AQM-37	31 May 61		4.5	2900+	Many (b)
North American XF-108	Not Flown	3.2	NA	0	0
Bristol T.188	14 Apr 62	3.0	1.88	2	78
Lockheed A-12/YF-12/SR-71	26 Apr 62		3.3+	50	Many (b)
Mikoyan/Guryevich Mig-25	6 Mar 64	2.83	3.2	900	Many (b)
North American XB-70	21 Sept 64		3.08	2	
Lockheed D-21	1964	4+		38	
Sukhoi T-4	22 Aug 72	3.0	1.28	1	9
Orbital Sciences Corp. Pegasus	5 Apr 90		8.2		5 (b)

a - Powered flights + about 7 unpowered flights.

b - Flights Continuing

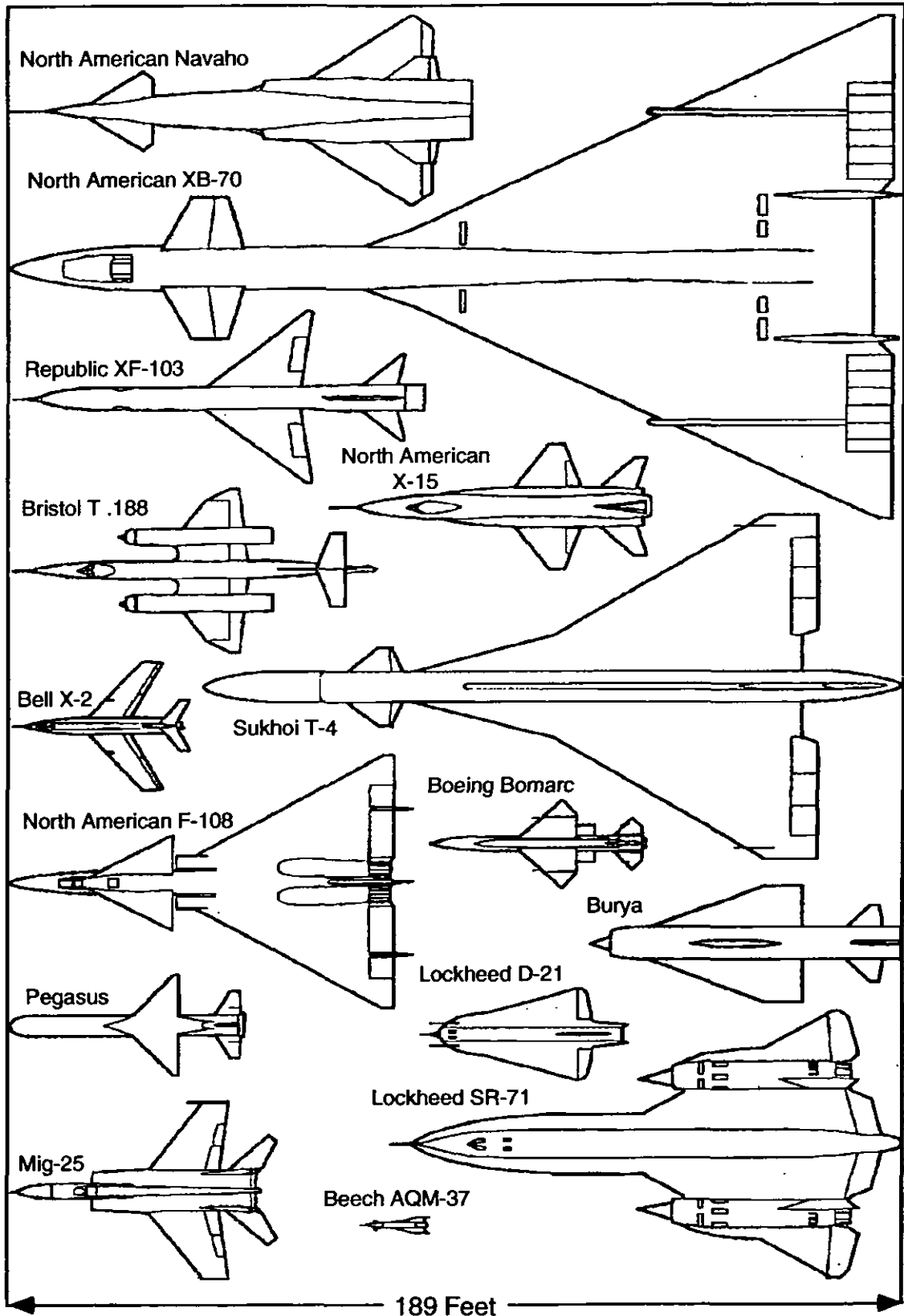


Figure 2 - Fifteen Aircraft Designed for Mach 3+

accident, the D-21 was fitted with a booster rocket and thereafter launched from a B-52.

Russian success at conquering Mach 3 was realized with the Mig-25 Foxbat. After Victor Belenko, a defecting Soviet pilot, landed his Mig-25 in Japan, much was uncovered about the Mig-25 performance. US authorities had tracked the Mig 25 in amazement at Mach 3.2 over Israel in 1973; however, Belenko said the Mig-25 could not safely fly above Mach 2.8. It seems everytime the Mig-25 was flown Mach 3.2, the engines were completely ruined and had to be replaced.

The Pegasus launch vehicle, dropped from either a B-52 or modified L-1011, operates as an aerodynamic vehicle until the first stage motor burns out above Mach 8.

Propulsion Features

Early Mach 3+ vehicles required rocket propulsion to reach the desired speeds. Rockets provided the advantage of not requiring atmospheric oxygen, thus eliminating ram drag and complex engine inlets. Pure ramjets offered a simple and inexpensive propulsion system for Mach 3 cruising; however, they required a boost to obtain ignition flight speed. An integrated ramjet/turbojet propulsion concept proved a good compromise for some manned vehicles (XF-103 and SR-71) developed in the USA. Turbojet engine development made possible manned aircraft such as the XB-70 and Mig-25 Foxbat. Table 2 summarizes the propulsion systems of Mach 3+ aircraft.

Table 2 - Propulsion Systems of Mach 3+ Aircraft

	Rocket	Rocket Booster & Ramjet Sustainer	Turbojet
Unmanned	AQM-37 Pegasus	Bomarc Navaho Burya D-21	
Manned	X-2 X-15		XF-103 XF-108 T.188 A-12/YF-12/SR-71 Mig-25 XB-70 T-4

The Mig-25 operated in excess of Mach 3 only rarely because the engines were destroyed in the process. The SR-71 and the XB-70 were the most successful of the ramjet / turbojet and turbojet powered Mach 3+ aircraft. Engine inlet design is critical in order to achieve efficient Mach 3 flight. These turbojet aircraft, (SR-71 & XB-70) plus the Sukhoi T-4, incorporated variable mixed compression inlets to efficiently slow down the ambient air so it could enter the engine at a reasonable speed. Mixed compression inlets provide good inlet recovery, but are susceptible to inlet "unstart." When unstart occurs, the shock that normally exists within

the inlet is forced out, resulting in reduced inlet recovery, engine thrust and an increase in inlet drag. This results in an aircraft yawing moment which translates into flight control problems for the pilot. External compression inlets like those on the F-14 and F-15 do not experience the unstart phenomena.

Aerodynamic Characteristics

The variety of vehicle configurations used in pursuit of Mach 3+ are shown in Figure 2. Ten of the 15 configurations use a delta wing, and five employ a canard arrangement. Canopy drag reduction schemes took some interesting approaches on the XF-103, XB-70, and T-4. The canopy on the XF-103 was eliminated altogether, using only side windows and a periscope for takeoff and landing. Movable fairing sections in front of the windscreen were provided on the XB-70 and T-4 to reduce drag. This arrangement produced lower drag during high speed operations yet provided adequate visibility for takeoff and landing. Another XB-70 aerodynamic feature was the fold down wing tips. As the aircraft reached Mach 3 cruise speed, wing tips were folded down 65° so that the aircraft could ride on its own shock wave.

Material Features

One of the problems associated with flight above about Mach 2.5 is the high temperature of the environment. When air at high Mach number impacts the wing and flight control leading edges, its kinetic energy raises the temperature to the stagnation temperature. In addition, air flowing past the surface of the fuselage or wing will reach the adiabatic wall temperature. Both of these temperatures are a function of Mach number, and their values are shown in Figure 3.

Aluminum loses its strength above about 350°F and melts at 1220°F. Obviously, materials other than aluminum are needed for flight at these high speeds. Titanium adds additional working margin up to about 900°F but requires

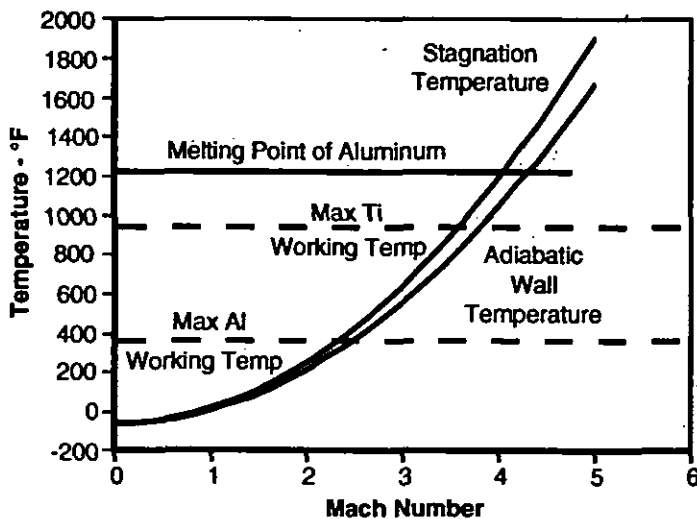
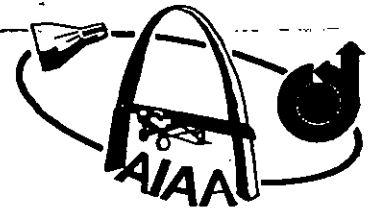


Figure 3 - Effect of Mach Number on Temperature

AIAA



**American Institute of Aeronautics and Astronautics
St. Louis Section**

**Nominations Solicited
for
1997 Section Awards**

Members of the St. Louis Section AIAA strive to recognize significant contributions. In that regard, we need your recommendation on worthy individuals for St. Louis Section awards. A few moments of your time spent nominating an individual or Team will give recognition to those who have helped advance the aerospace profession. Nominations are being accepted for the following awards to be presented at the annual Honors and Awards Dinner in May 1997. The awards reflect a broad range of recognition.

Technical Contribution: *In recognition of an outstanding contribution to the advancement of the aerospace sciences in a technical discipline by a section member or team of members.*

Technical Management: *In recognition of an outstanding accomplishment in technical management by a section member or team of members.*

Section Service: *In recognition of outstanding contributions to Section Activities by a member.*

Civic Award: *In recognition of outstanding contributions to the progress of aerospace activities in the St. Louis area by a member or non-member.*

The history of these awards spans several decades. Recipients cover a wide spectrum of individuals ranging from corporate leaders to researchers to congressmen to engineers to journalists. The significance and prestige of the awards cannot be overstated. It is viewed as a great honor by prior recipients. Further, St. Louis is one of the few sections in all of AIAA that has a heritage of bestowing such awards on an annual basis.

If you are associated with individuals whose achievements merit candidacy for one of these awards, submit a nomination on their behalf.

Review of nominations by the Selection Committee will commence 1 April 1997. The Committee needs your participation and encourages you to expend time and effort nominating worthy individuals. Please help us preserve a rich heritage and St. Louis tradition!

Submit Nomination to:

Ronald E. Smith, AIAA Honors and Awards Committee Chairman
McDonnell Douglas Aerospace, PO Box 516, MC 106-2255 St. Louis, MO 63166

AIAA



**American Institute of Aeronautics and Astronautics
St. Louis Section 1997**

**St. Louis Section AIAA Award Nomination
Nomination must be received by 1 April 1997**

1. Indicate the Award:

- * Technical Contribution
- * Section Service
- * Technical Management
- * Civic

2. Nominee:

Name: _____

Title/Position: _____

AIAA Membership Grade:

- * Associate Member
- * Member
- * Senior Member
- * Non-member
- * Associate Fellow
- * Fellow
- * Honorary Fellow

3. Proposed Citation:

Statement in 25 Words or less of the achievement upon which the nomination is based:

4. Basis for Nomination:

On separately attached sheets, please set forth the basis for the nomination including discussion of the importance of the achievement with specific evaluation of success in its practical application. The discussion should make clear the times and dates involved and specific ways in which the requirements of the award are met. Technical award nominations should include a list of publications, technical reports, conference papers, lectures, and patents relevant to the achievement under consideration. Avoid generalities. Stress personal accomplishment.

5. Nominator:

Name: _____ Phone: _____

Organization: _____

6. Letters of Recommendation: (Optional)

The nomination may be supported by letters of recommendation attesting to the importance of the achievement.

Please furnish all relevant information; missing data cannot be obtained elsewhere. The submitted material will constitute the total case as it will be presented to the Honors and Awards Committee:

7. Submit Nomination to:

Ronald E. Smith, AIAA Honors and Awards Committee Chairman
McDonnell Douglas Aerospace, P.O. Box 516, MC 106-2255, St. Louis, MO 63166

Table 3 - Structural Materials of Mach 3+ Aircraft

Aircraft	Structural Materials
Bell X-2	Steel & K-monel
North American Navaho	Titanium
Larochkin Burya	Titanium
North American X-15	Inconel X
Republic XF-103	Titanium
Bristol T.188	Steel
Lockheed A-12/YF-12/SR-71	Titanium
Mikoyan / Guryevich Mig-25	Steel & Titanium
Lockheed D-21	Titanium
Sukhoi T-4	Steel & Titanium

special processes and handling. Table 3 summarizes the structural materials employed on several of the Mach 3+ aircraft.

In addition to these structural materials, the X-15 and Pegasus incorporated ablative coatings that insulate the underlying material from the high temperatures.

Summary

The majority of Mach 3 aircraft research was performed between 1952 and 1964. Of the 15 vehicles intended to fly Mach 3+, only 11 actually made it. Two (XF-103 & XF-108) were canceled before they flew, and two were canceled before they reached Mach 3. Only four or five of these aircraft continue to be flown at Mach 3. The Russian Mig-25 continues in service, but it is unlikely to fly above Mach 2.8 very often. And the number of times it actually exceeded Mach 3 is also probably very small. Three or four SR-71's continue in service with the USAF and NASA, and probably exceed Mach 3 regularly.

NASA has recently acquired four D-21's for possible future research and are currently in storage. It is assumed that the AQM-37's may still occasionally fly at Mach 3+ as target drones. The Pegasus is an active program with a stretched version of the Pegasus having been developed, a Lockheed L-

1011 having been modified to launch them, and a facility in use which will allow 12 launches per year. There are rumors of a high speed reconnaissance aircraft named Aurora, but if anyone has seen it, they are not talking.

Future high speed manned aircraft are planned as a means of getting people and supplies to and from low earth orbit. The X-33 is envisioned as a Mach 15+ RPV that should start flying in 1998, while the X-34 is a Mach 8 vehicle expected to fly in 1999. These experimental aircraft could lead to larger aircraft capable of flying into space. Mach 3 commercial transports have been discussed from time to time, but nothing has developed yet. But all of this is very expensive, and only time will tell what will actually come to pass.

References:

1. British Experimental Jet Aircraft by Barrie Hygate
2. U. S. Bombers 1928 to 1980s by Lloyd Jones
3. X-Fighters by Steve Pace
4. "Storm in Midair" by Igor Shevalyov & Alexei Fomichev, Military Parade Magazine, March/April 1996
5. Air International, Volume 51, No.'s 2 & 3
6. Lockheed Aircraft Since 1913 by Rene Francillon
7. OKB Sukhoi, A History of the Design Bureau and Its Aircraft
8. Mig, Fifty Years of Secret Aircraft Design
9. Mig Pilot by John Barron
10. An Illustrated Encyclopedia of the Worlds Rockets and Missiles by Bill Gunston
11. AAHS Journal, Volume 19, No 1, Spring 1974
12. Jane's All the World's Aircraft, 1970-71, 1977-78, and 1980-81
13. Popular Science, October 1970, pg 59
14. AIAA-93-0520 Aerodynamic Analysis of Pegasus
15. AW&ST, April 16, 1990, pg 24, June 20, 94, pg 16, June 17, 1996, pg 31, July 8, 1996, pg 21
16. NASA SP-60, X-15 Research Results, dated 1965

Web Sites of Interest

Industrial Design Society of America

<http://www.idsa.org/>

National Space Society

<http://www.nss.org>

Planetary Society

<http://planetary.org/tsp/>

Space Policy Institute

<http://www.gwu.edu/~spi>

Space University

<http://www.space.edu>

The Design Council (U.K.)

<http://design-council.org.uk/welcome.html>

Comet Hale-Bopp

<http://www.skypub.com/comets/comets.shtml>

Send us your e-mail address

Save A Tree



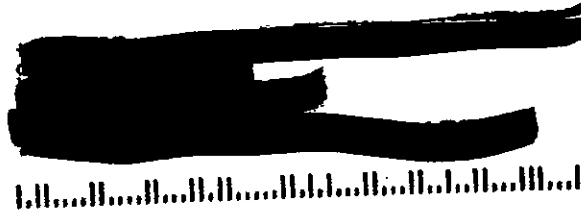
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Future AIAA Events

AIAA Council Meeting

Monday, 7 April
5:00 pm - 7:00 pm
MDA HQ, Level 2S
Conference Room



AIAA Dinner Meeting

Friday, 18 April
Henry VIII Hotel
Aviation Author; Bill Sweetman
"Aerospace Horizons in the Next
Century: Darth Vader Your Space
Shuttle Is Ready"

*Dinner meeting in conjunction
with AIAA Region V Student
Paper Conference*

Volunteers Needed

Region V Student Paper Competition - Friday, 18 April, Henry VIII

Industry Evaluators of

- Presentation Technique
- Technical Content

Sign Up for

- 2 Hour Volunteer Shifts
During the Day

Contact: Paul Czysz

(314) 434-2188

czysz@pxa.slu.edu