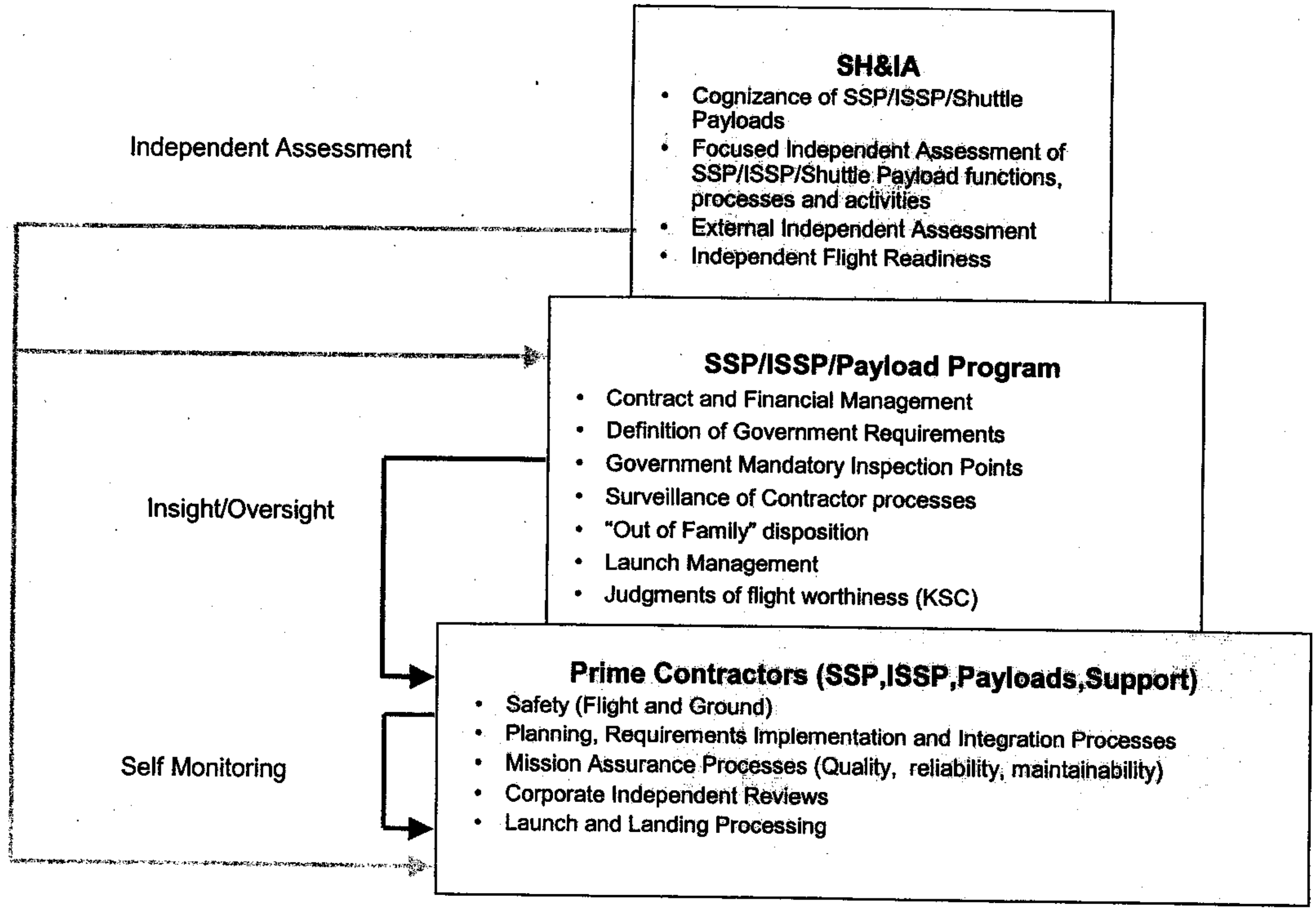
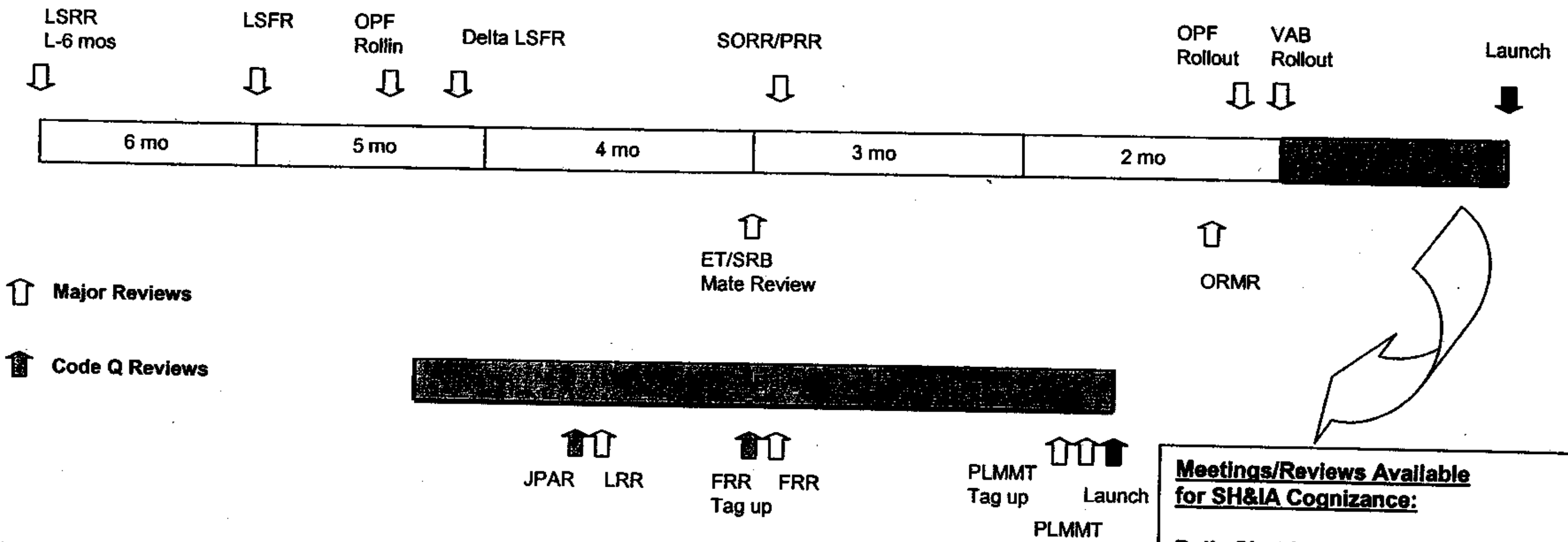
Three-Tiered Approach to Safety and Mission Assurance



SH&IA Assessment (Insight) of Flight Readiness

- SH&IA On-going COGNIZANCE through
  - Daily interactions with line S&MA organizations by attendance and participation in meetings, reviews and boards
  - Analysis of center safety metrics
  - Variance approval (Agency Level)
  - Safety and Mission Assurance Board
  - Safety and Health Council
  - Participation in other KSC Councils and Boards
- Performance of FOCUSED INDEPENDENT ASSESSMENTS of line organizations areas of responsibility
  - Primary customers are KSC Directorates
  - HEDS's Code Q Independent Assessment
- Review of EXTERNAL ASSESSMENTS
  - Code Q Process Verifications and other assessments
  - Office of Inspector General Audits
  - Aerospace Safety Advisory Panel Reviews
  - General Accounting Office Reviews
- Contracted external experts used to augment Center skills, as required

SSP/ISSP/Payloads SH&IA Mission Cognizance



ACRONYMS:

LSRR - Launch Site Requirements Review
LSFR - Launch Site Flow Review
ORMR - Orbiter Rollout Management Review
JPAR - Joint Prelaunch Assessment Review
LRR - Launch Readiness Review
FRR - Flight Readiness Review
PLMMT - Prelaunch Mission Mgmt Team
ISS - International Space Station
ISS - ISS-MEIT Multi-element Integration Test
CoFR - Certification of Flight Readiness
SORR - Stage Operations Readiness Review

Daily Project Status Documents for SH&IA Cognizance:

NTD Daily Issues Report
Engineering Log
PH S&MA Daily Status
ISS/Payloads Processing Status
USA Daily Report
USA Flash Reports
Boeing SHEA Reports

Meetings/Reviews Available for SH&IA Cognizance:

Daily Shuttle Project Status
Orbiter Technical Integration Telecon
SSP Stand-up Meetings
Orbital Integration Scheduling Meetings
OPF Scheduling Meetings
Daily Program Requirements Change Board
Program Review Control Boards (PRCB's)
Prelaunch Assessment Reviews
ISS S&MA Analysis & Integration Meetings
CoFR Reviews
Payload & MEIT Mission Planning Meetings
Launch Countdown Pre-test Briefings
HEDS IA Bi-weekly Status telecons
Launch Countdown Working Groups

Focused Independent Assessments

January 1, 2002 thru February 11, 2003

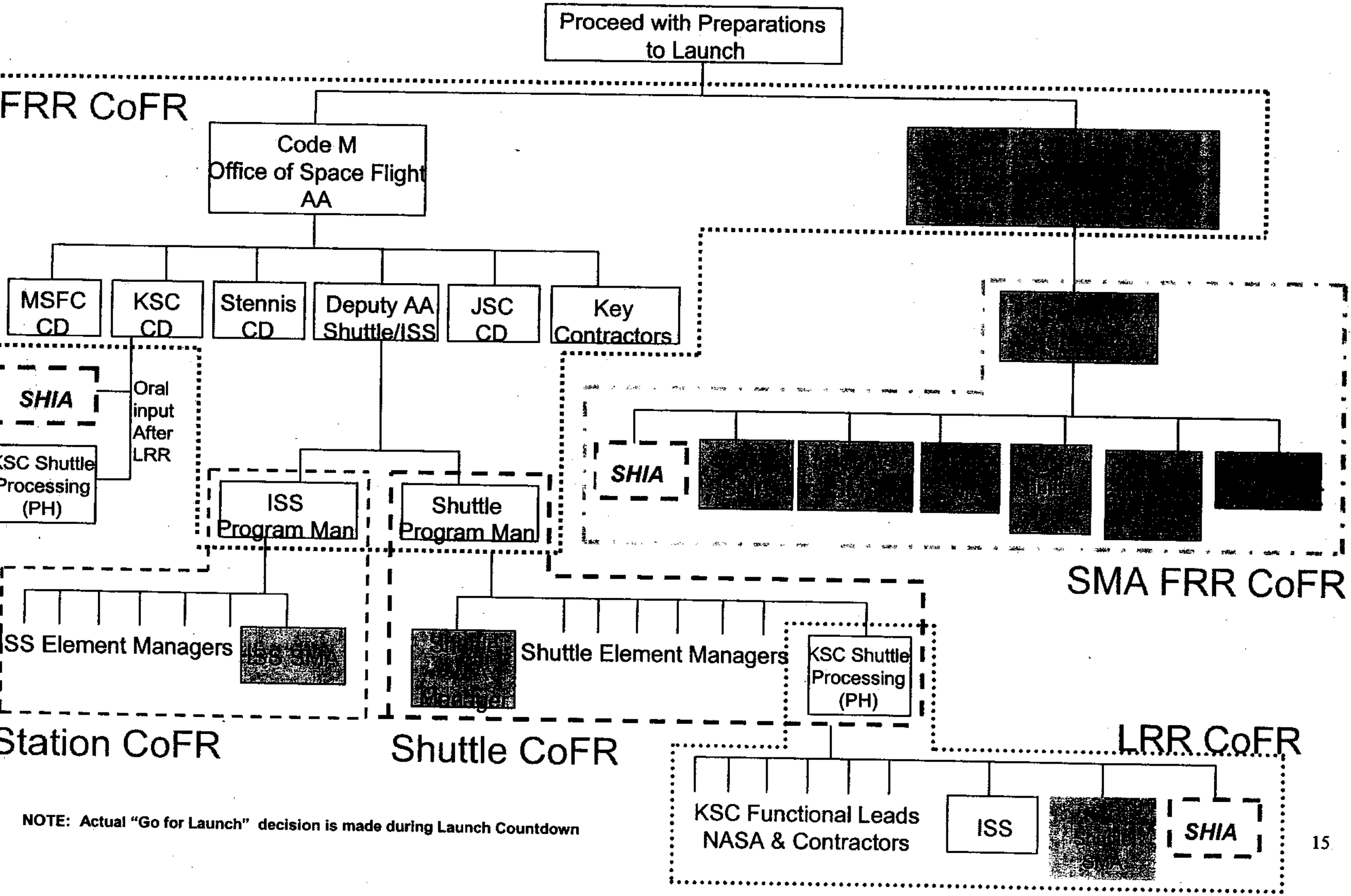
CATEGORY	NUMBER COMPLETED	OBSERVATIONS	EXAMPLES OF AREAS ASSESSED
Institutional	17	108	Confined Space, Quality Stamp Control, GIDEP, Lockout/Tagout, SCAPE Concerns
Shuttle	6	32	Shuttle Launch Team Use of Uncertified Data, STS-110 Orbiter Aft Closeout, Tool Control, Quality Stamp Control/Waranty - USA, Linear Shape Charges, CLCS Software
Station/Shuttle Payloads	4	19	ISSP QA Requirements Flowdown, Multiple Element Integrated Test (MEIT) Safety Concerns, SSPF Ammonia Plume Venting, SpacehabConfiguration Management

SSP / ISSP / Payloads Attribute List

KSC's primary focus is with launch processing and ground support equipment. For Shuttle and Space Station Flight Readiness Assessments, the following attributes are considered for launch readiness by SH&IA

- First Flight Items
- Mission Unique Interfaces
- Single Point Failures
- Launch Commit Criteria (LCC) Changes
- Operations and Maintenance Requirements Specification Document (OMRSD) Changes
- Hazard Analysis
- Mission Rule Changes
- Unexplained Anomalies
- Contingency Planning
- Alerts
- Software Changes
- Variances, Waivers & deviations
- Past Ground and Flight Anomalies
- Range Safety Issues
- Training
- Level of Mission Assurance
- NASA Safety Reporting System (NSRS)
- Lessons Learned Implementation
- Accepted / Residual Risk Status
- Vehicle / Ground Support Equipment (GSE) modification Status
- Limited Life Items
- Critical Process Changes
- Program requested items
- Maximum Worktime Deviations

Shuttle/Station "Notional" Certification of Flight Readiness (CoFR) Approvals



NOTE: Actual "Go for Launch" decision is made during Launch Countdown

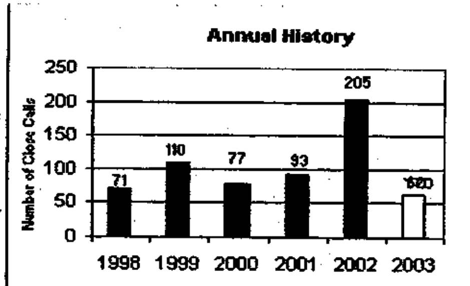
Selected Safety and Mission Assurance Metrics

KSC CLOSE CALLS
CIVIL SERVICE & CONTRACTORS

METRIC-0566
Jan-23-2003

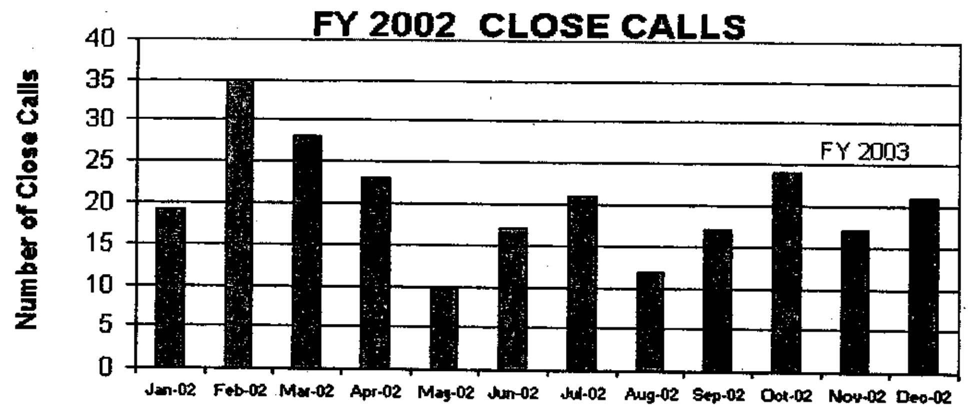
Goal Statement: To increase the number of close calls reported to prevent mishaps.
Metric Description: This metric counts the number and type of close calls reported by each of the KSC organizations. A **Close Call** is an event with no injury, no damage, injury requiring only first aid, or minor damage (less than $1,000), but with the potential to cause any type of mishap, including injuries, damage or mission impact.
Source: The IRIS Database.
Update Frequency: Monthly
Metric Owner: Bert Garrido/ Florence Patten
POC: Brenda Willis, 867-4523

Annual History



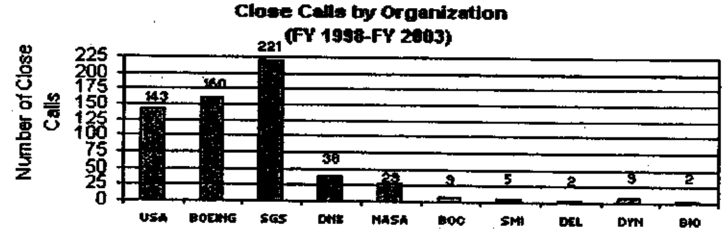
FY	1998	1999	2000	2001	2002	2003
TOTAL	71	110	77	93	205	62

FY 2002 CLOSE CALLS



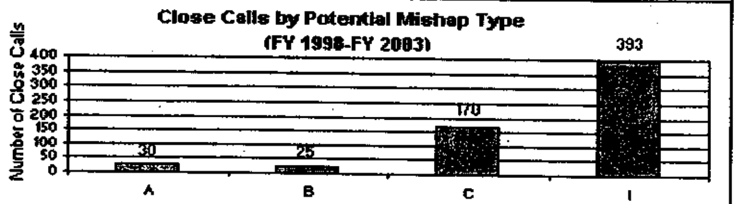
Month	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02
TOTAL	19	35	28	23	10	17	21	12	17	24	17	21
USA	1	2	3	2	0	1	0	0	3	3	1	0
Boeing	2	3	4	7	2	3	0	1	2	2	3	7
SGS	13	24	18	13	7	12	18	10	11	19	13	13
NASA	2	2	0	0	1	1	2	0	1	0	0	0
BIONETICS	0	2	0	0	0	0	0	0	0	0	0	0
DNX	0	0	2	0	0	0	0	0	0	0	0	1
DYNAMAC	1	2	1	1	0	0	1	1	0	0	0	0

Close Calls by Organization (FY 1998-FY 2003)



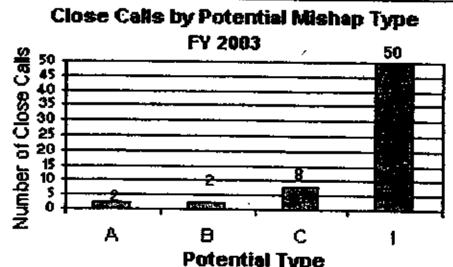
Organization	USA	BOEING	SGS	DNX	NASA	BOC	SMI	DEL	DYN	BIO
Close Calls	143	160	221	38	29	9	5	2	9	2

Close Calls by Potential Mishap Type (FY 1998-FY 2003)



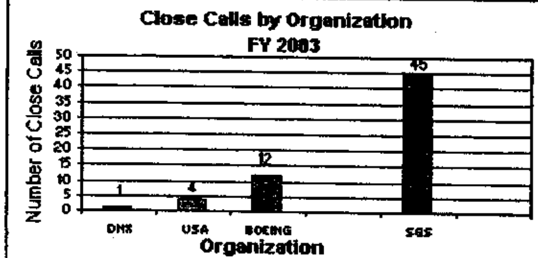
Potential Type	A	B	C	I	Total
Close Calls	30	25	170	393	618

Close Calls by Potential Mishap Type FY 2003



Potential Type	A	B	C	I
Close Calls	2	2	8	50

Close Calls by Organization FY 2003



Org.	DNX	USA	BOEING	SGS
Close Calls	1	4	12	45

Assessment: FY 2002 had an all-time high number of close calls reported over recent years. October, November and December started the first quarter of FY 2003 with 24, 17 and 21 close calls reported respectively. Of the 62 FY 2003 close calls, 2 had potential for Type A, 2 for Type B, 8 for Type C, and 50 for Type I (incidents). If the rest of the year continues at the current rate, KSC close calls will increase by approximately 20% over last year. **Actions:** Continued emphasis through reporting process improvement and at the Safety and Health Council.

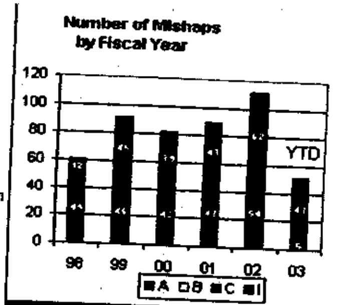
KSC MISHAPS
CIVIL SERVICE & CONTRACTOR

METRIC-0568
Jan-30-2003

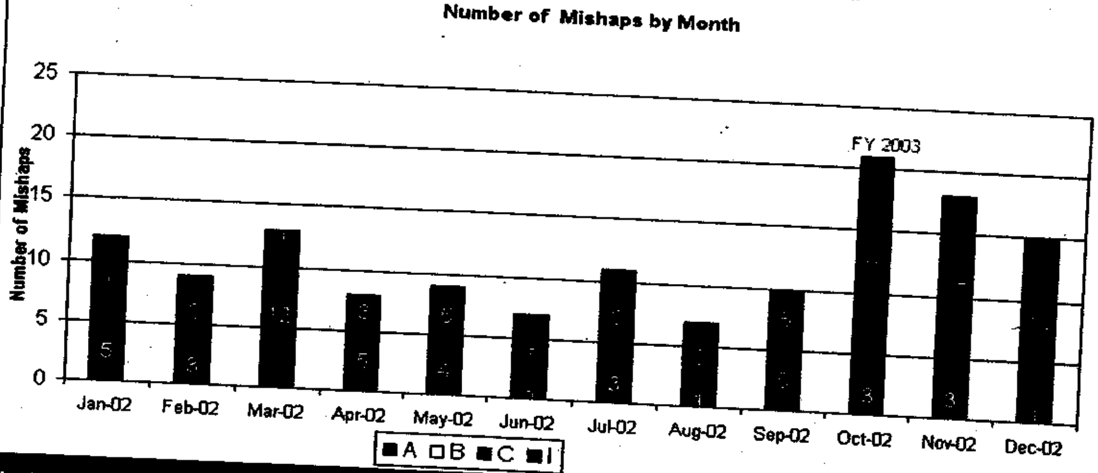
Goal Statement:
Decrease total number of type A, B, C, and I mishaps to zero.

Metric Description:
This metric measures the composite of type **A, B, C** and **I** mishaps for KSC civil service and contractor organizations. Type A Mishap: A mishap causing death, hospitalization of three or more persons, and/or damage to equipment or property equal to or greater than $1 million. Type B Mishap: A mishap resulting in permanent disability to one or more persons and/or damage to equipment or property equal to or greater than $250,000 but less than $1 million. Type C Mishap: A mishap resulting in damage to equipment or property equal to or greater than $25,000, but less than $250,000 and/or causing occupational injury or illness that results in a lost workday case. Type I (Incident): A mishap consisting of personal injury requiring medical treatment greater than first aid but without any lost time and/or property damage equal to or greater than $1,000, but less than $25,000.

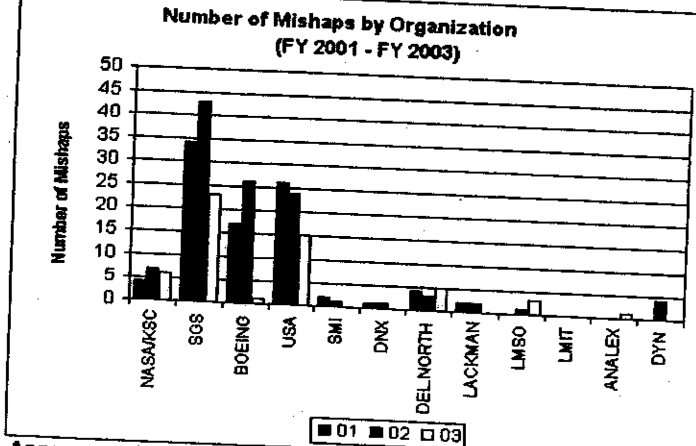
Source: The IRIS Database.
Update Frequency: Monthly
Metric Owner: Bert Garrido/ Florence Patten
POC: Brenda Willis, 867-4523

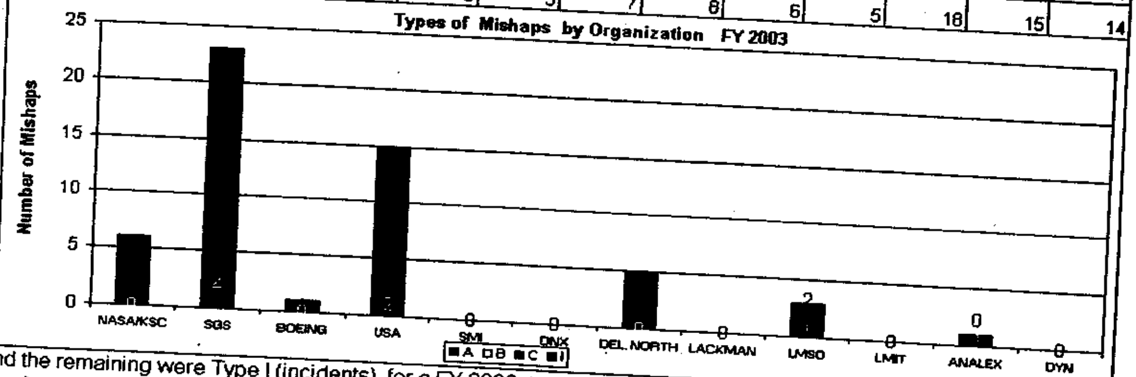


	98	99	00	01	02	03
	61	91	82	90	112	54
A						
B						
C	49	46	43	47	50	7
I	12	45	39	43	62	47



Month	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02
Total Mishaps	12	9	13	8	9	7	11	7	10	21	18	15
A												
B												
C	5	3	12	5	4	0	3	1	5	3	3	1
I	7	6	1	3	5	7	8	6	5	18	15	14





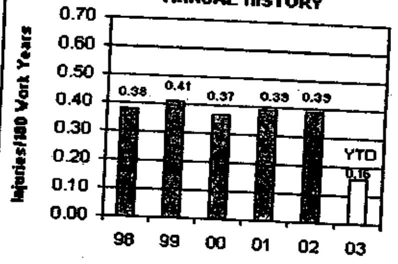
Assessment: In December, there were 15 mishaps, one (1) Type C and the remaining were Type I (incidents), for a FY 2003 total of 54. Of the 54 for FY 2003 thus far, seven (7) were Type C which included two (2) instances of property damage greater than $25,000, five (5) were lost time injuries and 47 were Type I (incidents). Although the number of mishaps is relatively high, the severity is lower (mostly incidents). **Actions:** Continued emphasis on mishaps, close calls and unsafe conditions through the Safety and Health Council, VPP, independent assessments and safety requirements in the procurement process.

KSC LOST TIME INJURIES (FREQUENCY) CIVIL SERVICE & CONTRACTOR

METRIC-0526
Jan-21-2003

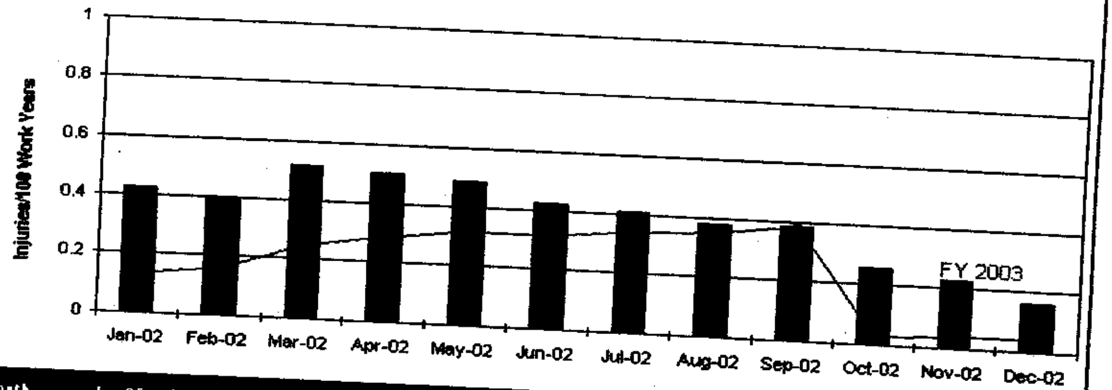
Goal Statement:
Decrease total number of Lost Time Injuries to zero.
Metric Description:
Measures the lost time injuries per 100 work years. The line on the FY 2002 Chart shows the year-end value if no further injuries occur. This metric is also known as "Time away from work."
Source: The IRIS Database.
Update Frequency: Monthly
Metric Owner: Bert Garrido/ Florence Patten
POC: Brenda Willis, 867-4523

ANNUAL HISTORY



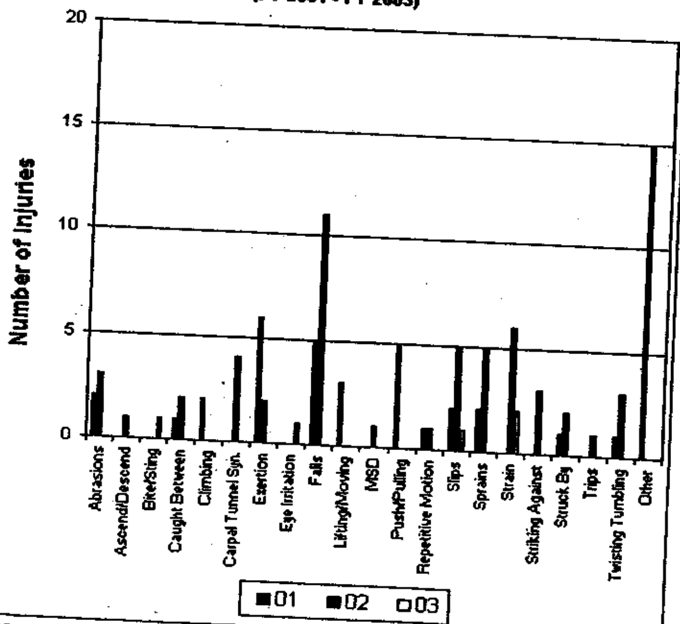
FY	98	99	00	01	02	03
Freq.	0.38	0.41	0.37	0.39	0.39	0.16
# LT Injuries	42	47	43	46	50	5

Monthly Cumulative Rate by Month

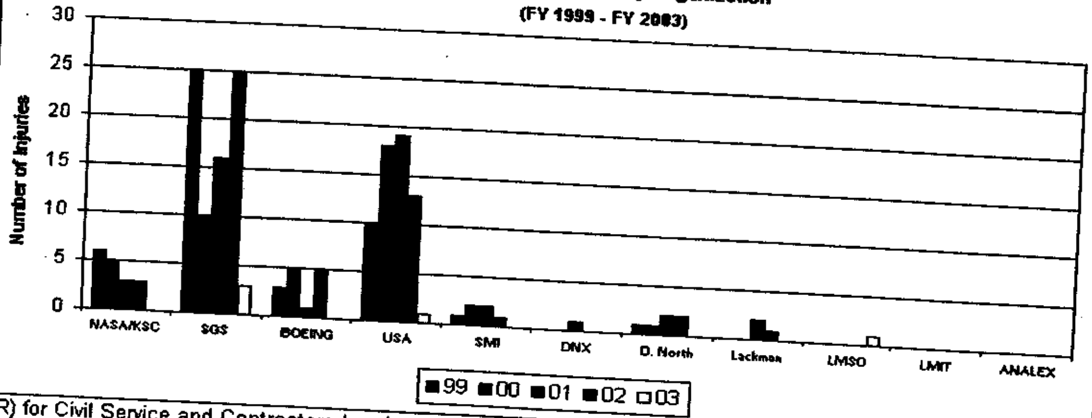


Month	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02
CUM FREQ	0.43	0.40	0.52	0.50	0.49	0.43	0.41	0.38	0.39	0.26	0.23	0.16
YEAR BEST	0.13	0.16	0.25	0.29	0.32	0.32	0.34	0.35	0.39	0.02	0.04	0.04
LT CASES	5	3	12	5	4	0	3	1	5	3	2	0
HOURS(K's)	2,094	2,149	2,257	2,389	2,139	2,243	2,249	2,235	2,135	2,352	2,050	1,829
CUM CASES	17	20	32	37	41	41	44	45	50	3	5	5
CUM HOURS	7,938	10,087	12,344	14,733	16,872	19,115	21,364	23,599	25,734	2,352	4,402	6,231

Number of Injuries by OSHA Type of Injury (FY 2001 - FY 2003)



Number of Injuries by Organization (FY 1999 - FY 2003)

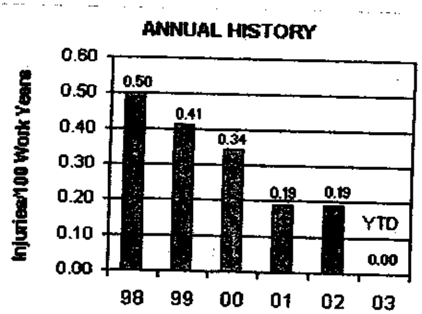


Assessment: Over recent years, the KSC Lost Time Injuries Rate (LTIR) for Civil Service and Contractors has been fairly consistent. For FY 2003, there have been 3 lost time injuries in October, 2 lost time injuries in November, and zero (0) lost time injuries in December, for a LTIR of .16. If no more lost time injuries occur this year, the LTIR would be .04.
Actions: Continued emphasis on close calls and unsafe conditions reporting and correcting through the Safety & Health Council, Spaceport Super Safety and Health Day and safety requirements in the procurement process.

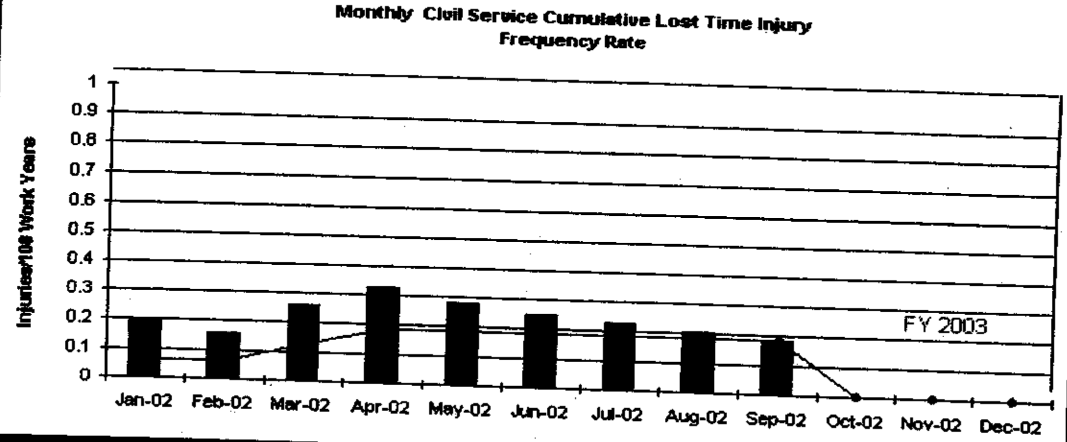
KSC LOST TIME INJURIES (FREQUENCY)
CIVIL SERVICE

METRIC-0525
Jan-21-2003

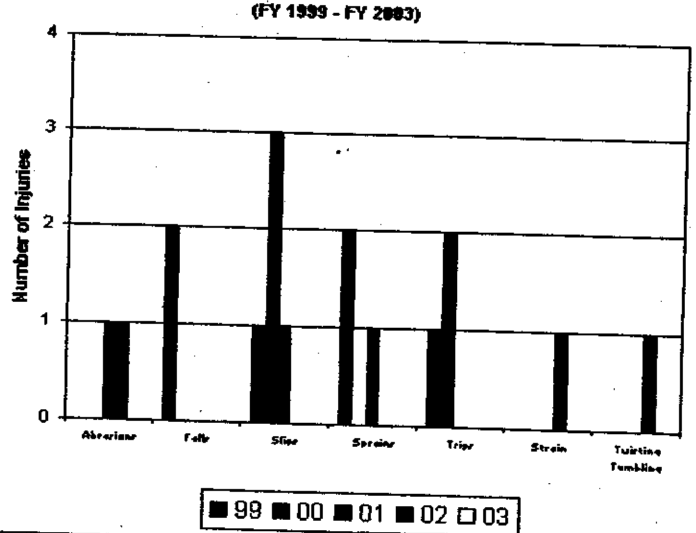
Goal Statement: Decrease total number of Lost Time Injuries to zero. (.20 was Headquarter's old goal)
Metric Description: This metric measures the number of injuries which result in time lost from work for each NASA KSC directorate. The units are the number of lost time injuries per 100 work years equivalents. The line on the FY 2002 Chart shows the year-end value if no further injuries occur. This metric is also known as "Time away from work."
Source: The IRIS Database.
Update Frequency: Monthly
Metric Owner: Bert Garrido/ Florence Patten
POC: Brenda Willis, 867-4523

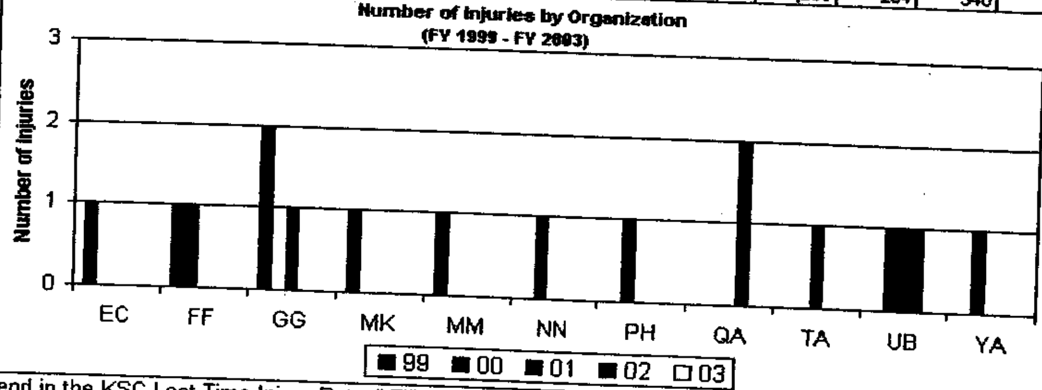


FY	98	99	00	01	02	03
Freq.	0.50	0.41	0.34	0.19	0.19	0.00
# LT Injuries	8	6	5	3	3	0



Month	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02
Frequency	0.20	0.16	0.26	0.33	0.28	0.25	0.22	0.20	0.19	0.00	0.00	0.00
YEAR BEST	0.06	0.06	0.12	0.19	0.19	0.19	0.19	0.19	0.19	0.00	0.00	0.00
LT CASES	0	0	1	1	0	0	0	0	0	0	0	0
HOURS (Ks)	258	262	289	291	289	268	274	285	277	294	246	210
CUM CASES	1	1	2	3	3	3	3	3	3	0	0	0
CUM KHOURS	1,003	1,265	1,554	1,845	2,134	2,402	2,676	2,961	3,238	294	540	750





Assessment: Over recent years, there has been a continuous downward trend in the KSC Lost Time Injury Rate (LTIR) for civil service until FY 2002. FY 2001 and FY 2002 both had 3 lost time cases and a LTIR of .19. The first three (3) months of FY 2003 have had no lost time cases and the LTIR remains at zero (0). There have been no civil service lost time cases for the last eight (8) months. **Actions:** Continued emphasis on close calls and unsafe conditions reporting and correcting as a means of mishap prevention.

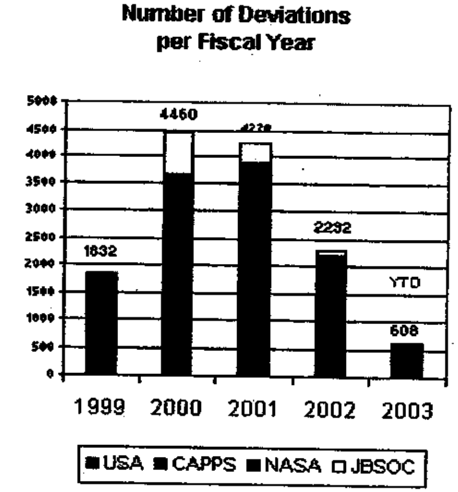
KSC MAXIMUM WORKTIME DEVIATIONS
CIVIL SERVICE & CONTRACTOR

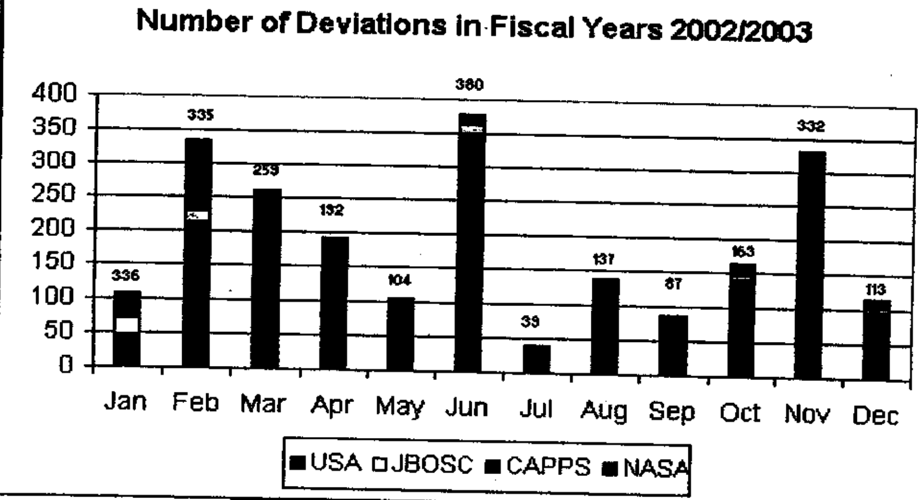
METRIC-0565
Jan-29-2003

Goal Statement:
Mimize the number of MWT deviations.

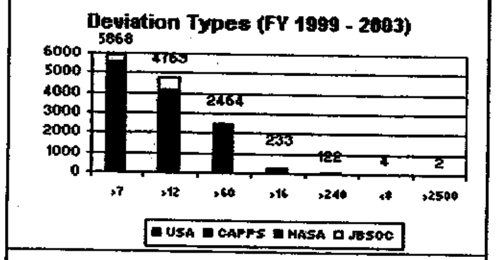
Metric Description:
This metric tracks deviations to the KSC maximum worktime limits for critical positions exceeding: a 12-hour workday, 7 consecutive days, 60-hour work week, 16-hour workday, 240 hours in a 4-week period, 2500 hours per rolling year, & failing to take 8-hours off between shifts. Organizations shown have critical positions.

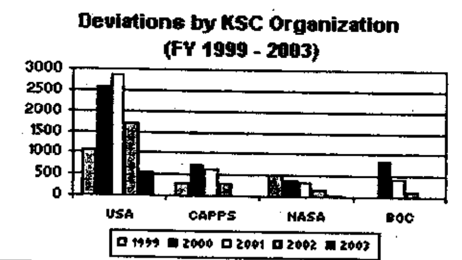
Update Frequency: Monthly
Metric Owner: Bert Garrido/ Florence Patten
POC: Linda Ackroyd, 867-3199

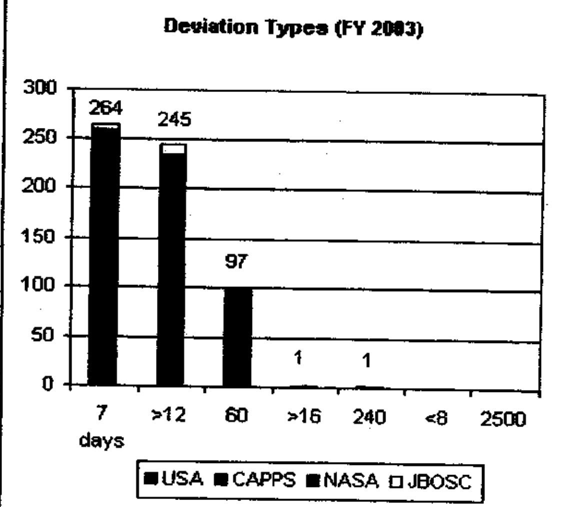


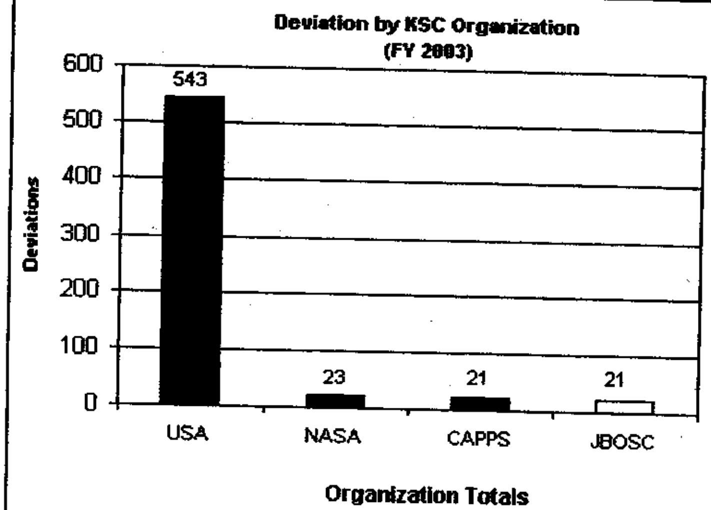


Historical Reference







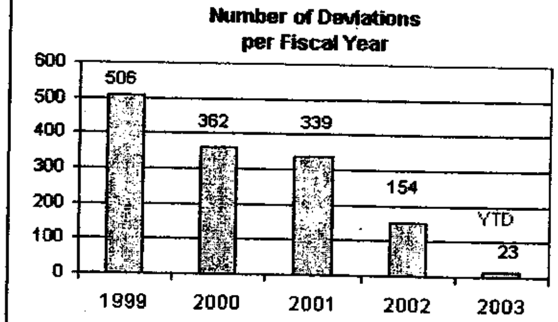


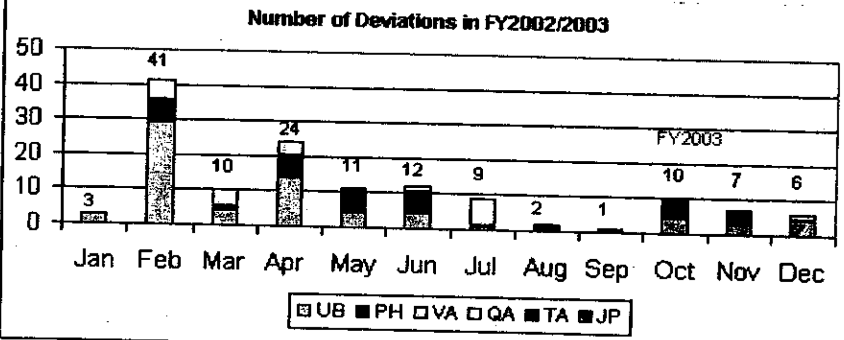
Assessment: The deviations for December were the result of supporting: GSE and test setups,launch campaign coverage for SORCE, WORF rack mechanism, STS-113 landing, STS-107 rollout, STS-115 to OPF, holiday heat plant support, power coordinators 24/7 shifts, Pegasus move to the MPPF, supported unavoidable extended GUPPY offload,and a late shipment to Dryden for possible Shuttle Landing, the 2500 deviation is primarily due to ISS Truss support. **Actions**: Continued emphasis on MWT deviations at the Safety & Health Council and independent assessments to ensure compliance with the new MWT policy.

KSC MAXIMUM WORKTIME DEVIATIONS
CIVIL SERVICE

METRIC-0564
Jan-29-2003

Goal Statement: Minimize the number of MWT deviations through proper planning.
Metric Description: Monthly deviations to KSC MWT limits for critical positions: exceeding a 12-hour workday, 7 consecutive days, a 60-hour work week, a 16-hour workday, 240 hours in a 4-week period, 2500 hours per rolling year, and less than 8-hours off between shifts. Organizations shown have critical positions.
Update Frequency: Monthly
Metric Owner: Bert Garrido/Florence Patten
POC: Linda Ackroyd, 867-3199





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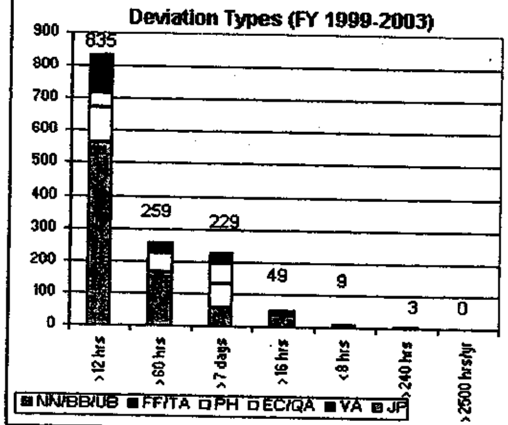

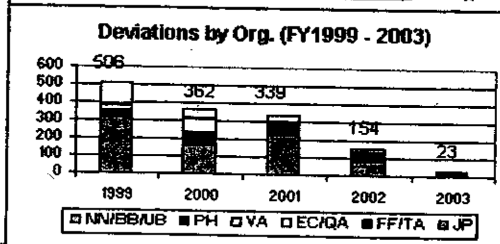

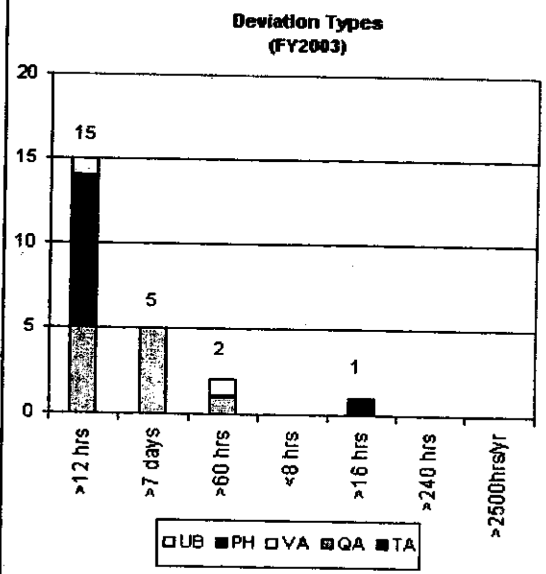

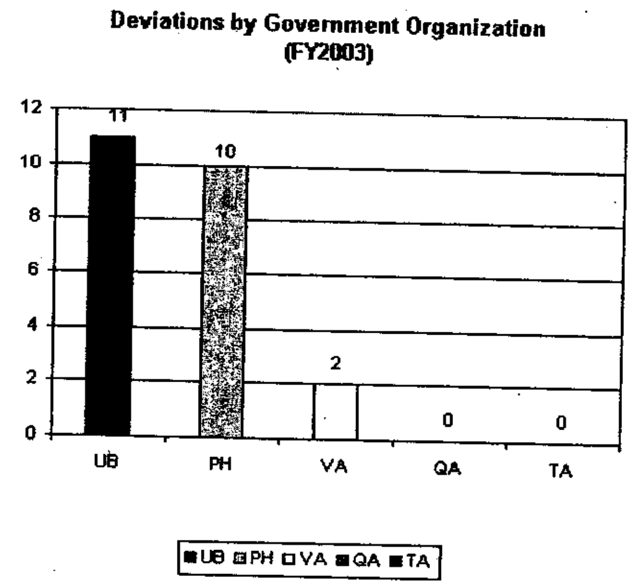

Assessment: There were six NASA deviations for the month of December. Deviations were in support of GSE and Test Setups, Launch campaign coverage for SORCE, and WORF Rack Mechanism

Actions: Continued emphasis on MWT deviations at the Safety & Health Council and independent assessments to ensure compliance with the new MWT policy.

X-Sender: a.h.phillips@pop.larc.nasa.gov
Date: Fri, 14 Feb 2003 13:37:21 -0500
To: "Pamela F. Richardson" <Pamela.Richardson@hq.nasa.gov>
From: "Alan H. Phillips" <a.h.phillips@larc.nasa.gov>
Subject: Fwd: Orbiter Mach 6 wind tunnel tests
Cc: "Peter J. Rutledge" <prutledg@mail.hq.nasa.gov>,
Jim Lloyd <Jlloyd@hq.nasa.gov>

Some wind tunnel results and information that LaRC is performing in support of JSC investigation activities.

Alan

X-Sender: r.a.wheless@express.larc.nasa.gov
Date: Thu, 13 Feb 2003 13:24:22 -0500
To: m.p.saunders@larc.nasa.gov
From: "Richard A. Wheless" <r.a.wheless@larc.nasa.gov>
Subject: Orbiter Mach 6 wind tunnel tests
Cc: a.h.phillips@larc.nasa.gov

Mark
Please find attached the power point presentation that I made to JSC today. The presentation summarizes the experimental aerothermal work that has been accomplished over the past 4 days of wind tunnel testing. I believe Vince Zoby will be presenting the information to the folks at 1219 today at 4pm. Mike DiFulvio has indicated your interest in coming over to the tunnel sometime. No problem...We will be here today until 8pm tonight and will revert back to a standard shift on friday. Number at the tunnel 45744. Testing will resume next Tuesday...
Hope this helps
Regards,
Tom Horvath

Richard A. Wheless

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Orbiter windward thermal mappin

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****

LaRC Wind Tunnel Testing in Support of Orbiter External Aerothermodynamics

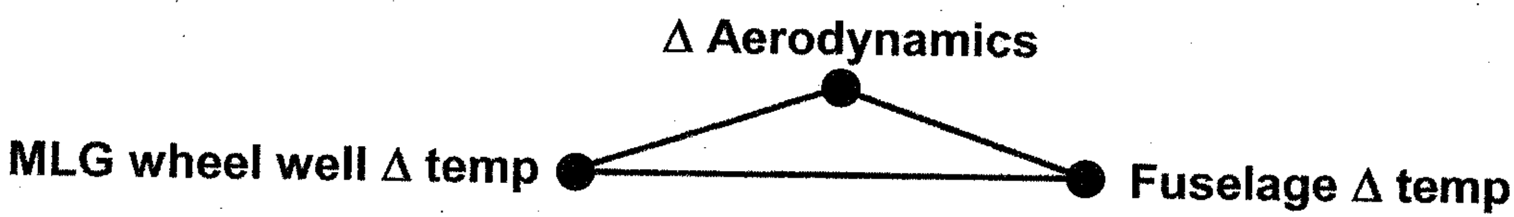
Status Report
February 13, 2003

Thomas J. Horvath
Aerothermodynamics Branch
NASA Langley Research Center

LaRC Near Term Experimental Aerothermodynamic Support

Objective

- Provide rapid assessment of localized OML shape changes on Orbiter aerothermodynamics and aerodynamics



Motivation

- Most failure scenarios involve leading edge/acreage TPS damage

Approach

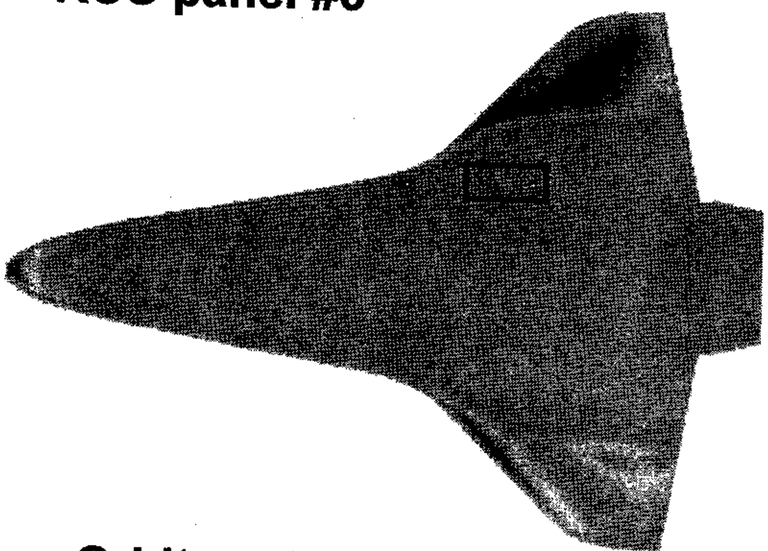
- Closely coupled aerodynamic and heat-transfer ground based testing

Simulated surface discontinuity	Aero	MLG wheel well	Fuselage
Protuberance	Asymm b.l. transition	Laminar/turb heating augmentation	Heating augmentation
Cavity	Asymm b.l. transition	Laminar/turb heating augmentation	Heating augmentation

Wing Leading Edge OML Sensitivity Study

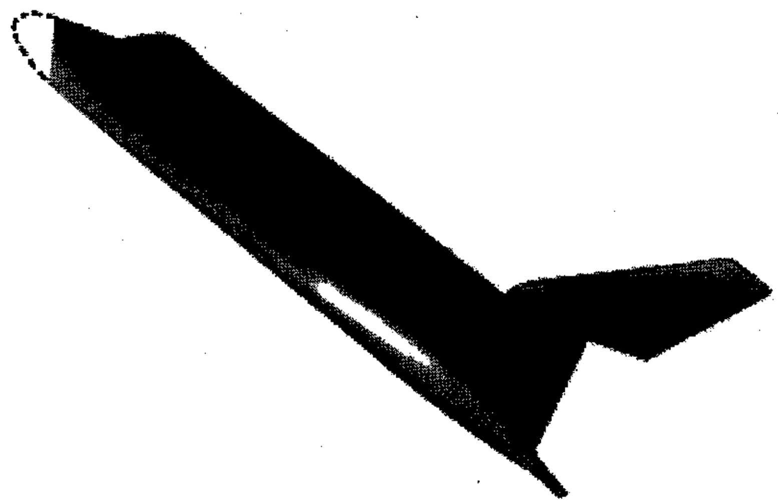
- Tunnel occupancy to date (1-12-03) : 4 days
- Facility: NASA LaRC 20-Inch Mach 6
- Deliverables: Global surface temperature mappings to infer b.l. transition. Global heating to determine augmentation levels above laminar levels.

Leading edge protuberance
RCC panel #6



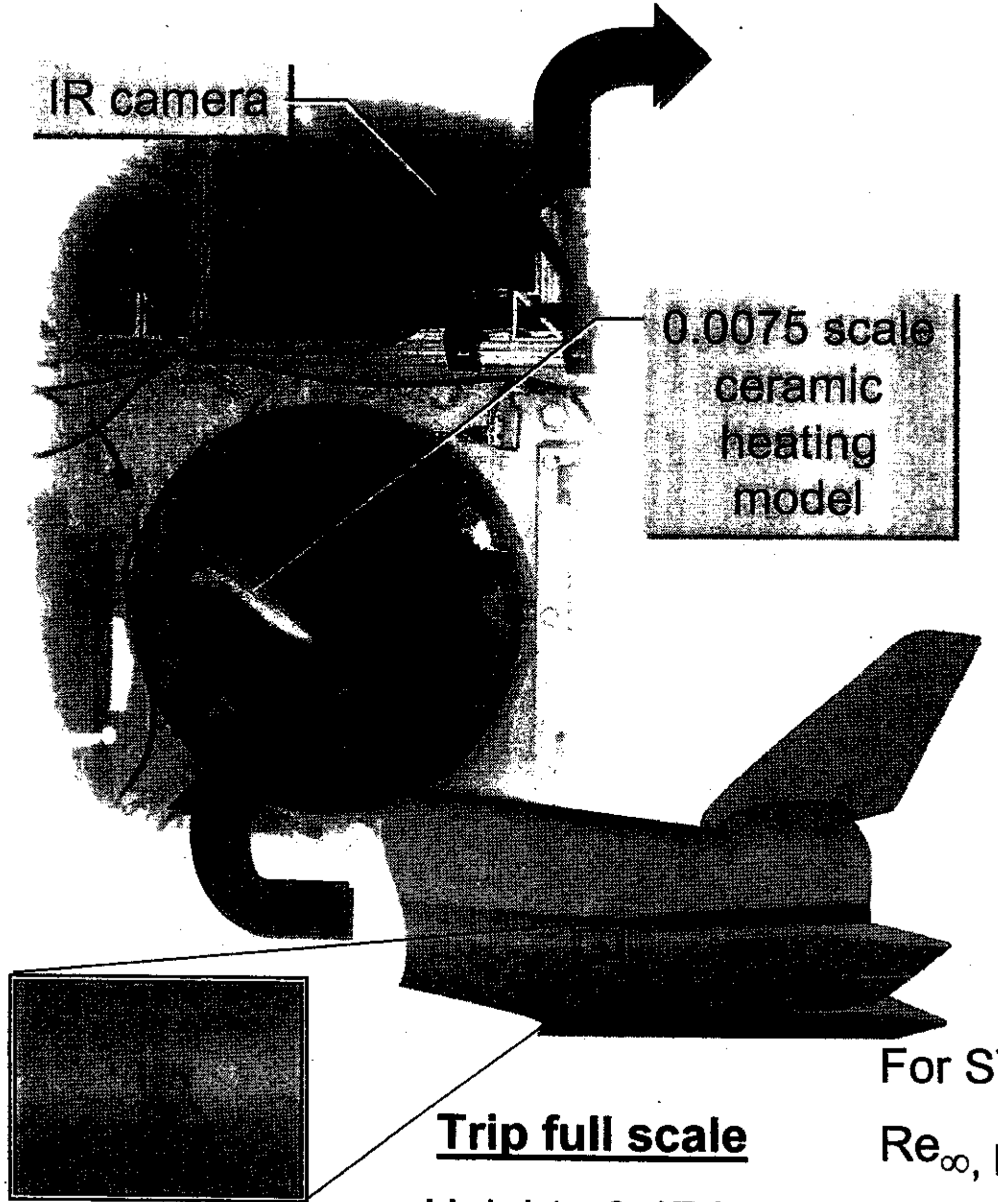
Orbiter windward surface

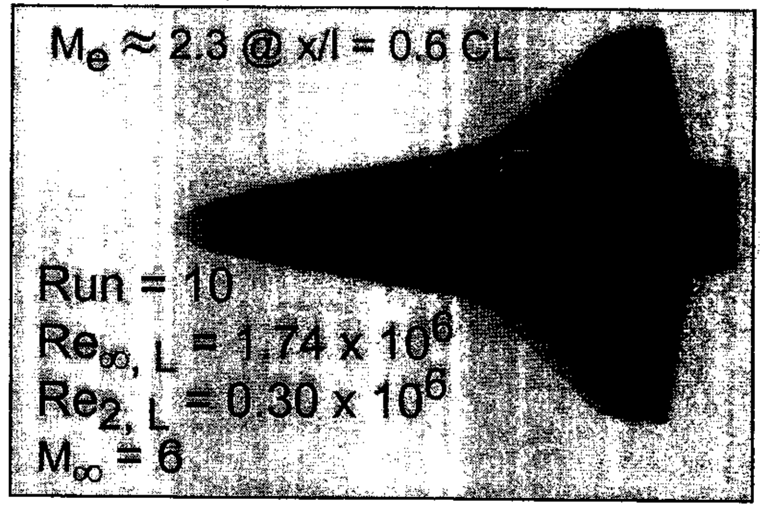
Leading edge cavity
RCC panel #6

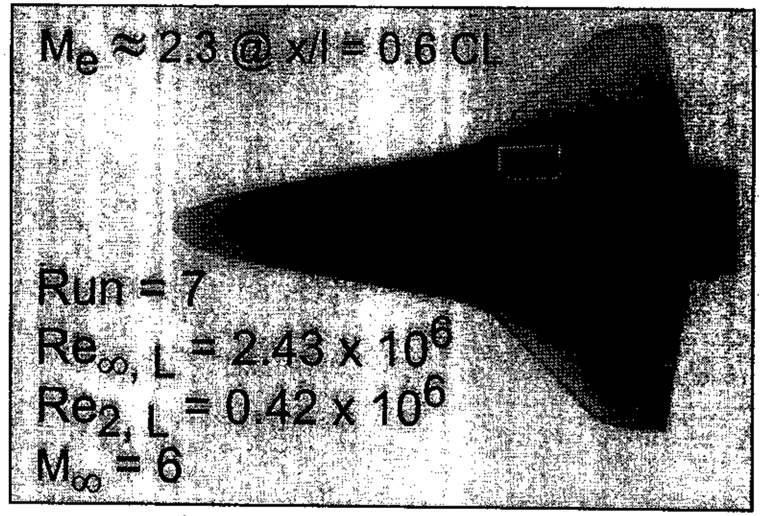


Orbiter side fuselage

Orbiter L.E. Sensitivity Study







Trip full scale

Height 0.47-in
Size 13 x 13-in

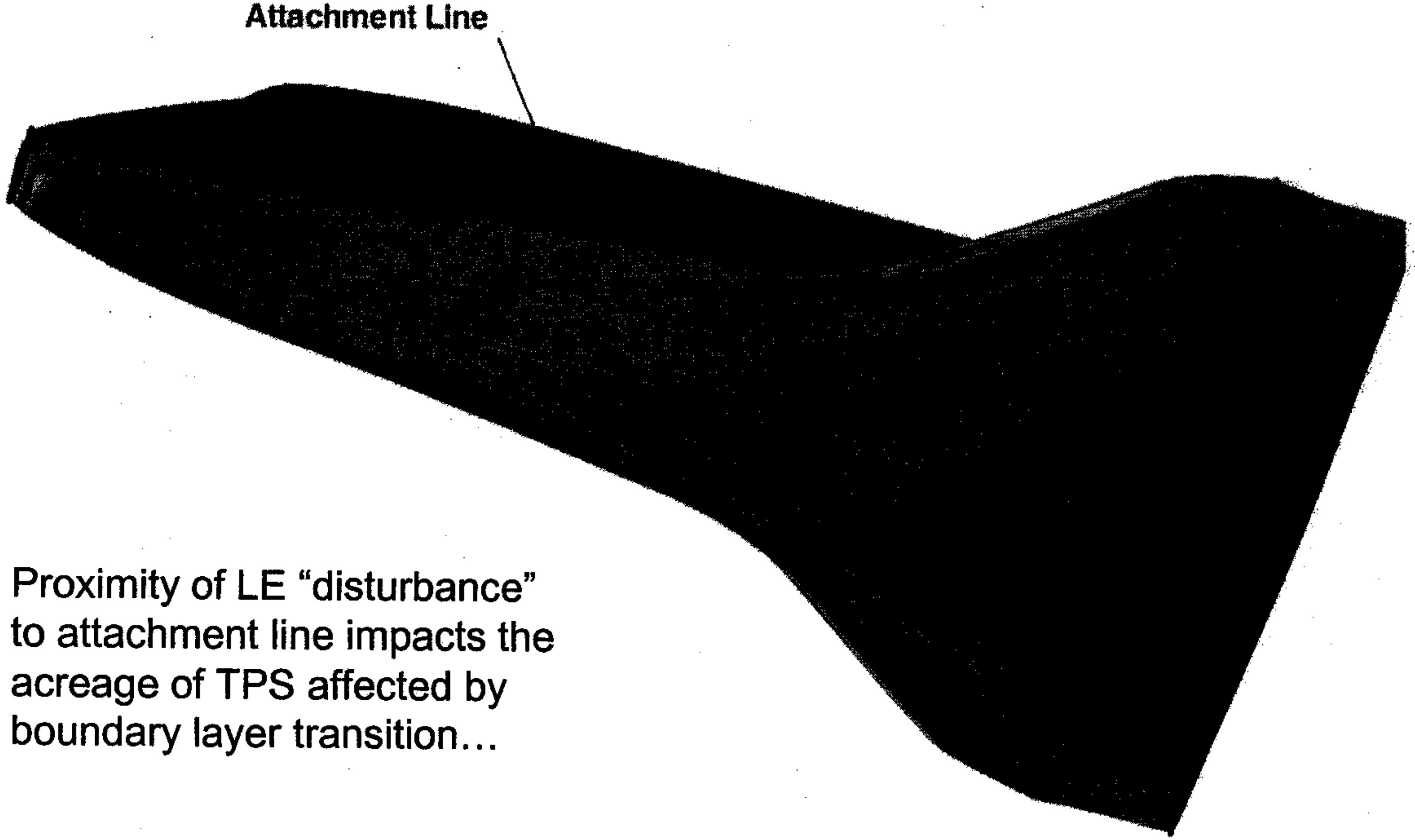
For STS-28 Early Transition $M_\infty = 17.9$

$Re_{\infty, L} \approx 2.4 \times 10^6$
$Re_{2, L} \approx 0.4 \times 10^6$
$M_e \approx 3$ @ x/l = 0.6 CL

Bouslog
OEX Aerothermo Sym
1995

Shuttle Orbiter Surface Streamlines

LAURA Inviscid $M_\infty = 6$, $\alpha = 40$ deg



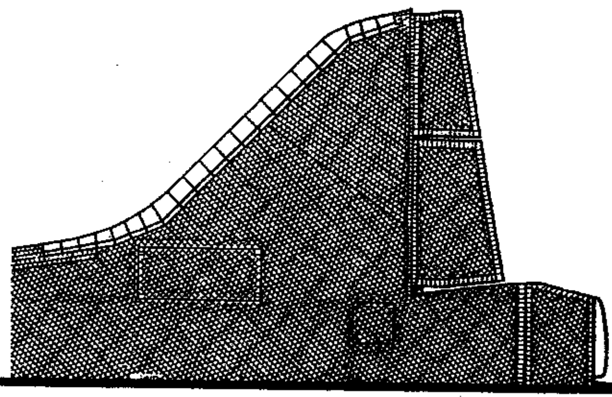
Proximity of LE "disturbance" to attachment line impacts the acreage of TPS affected by boundary layer transition…

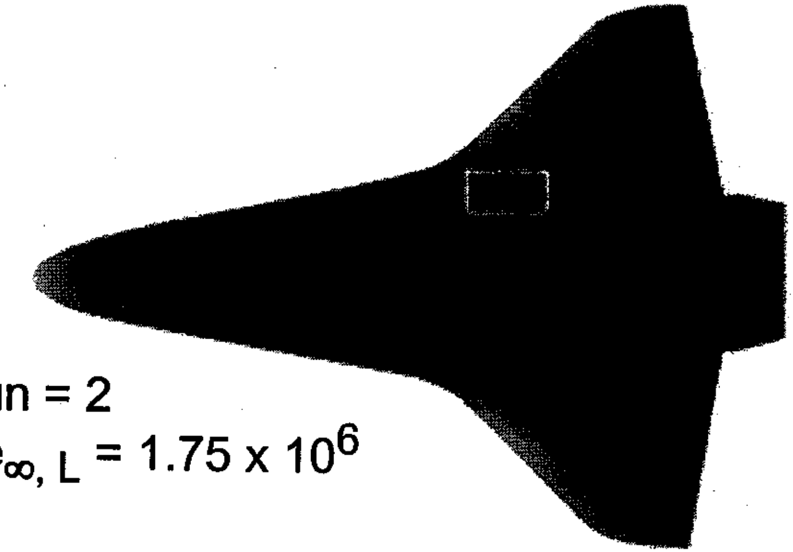
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

NASA LaRC 20-Inch Mach 6 Air

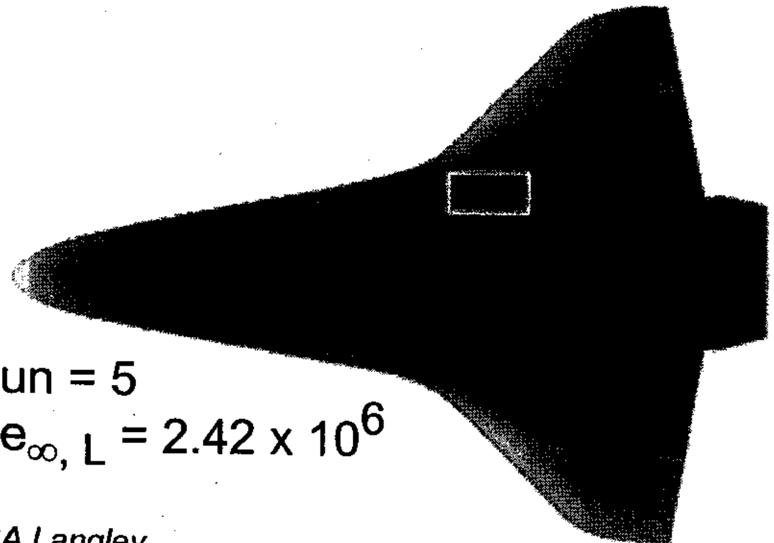
α = 40 deg   Baseline   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

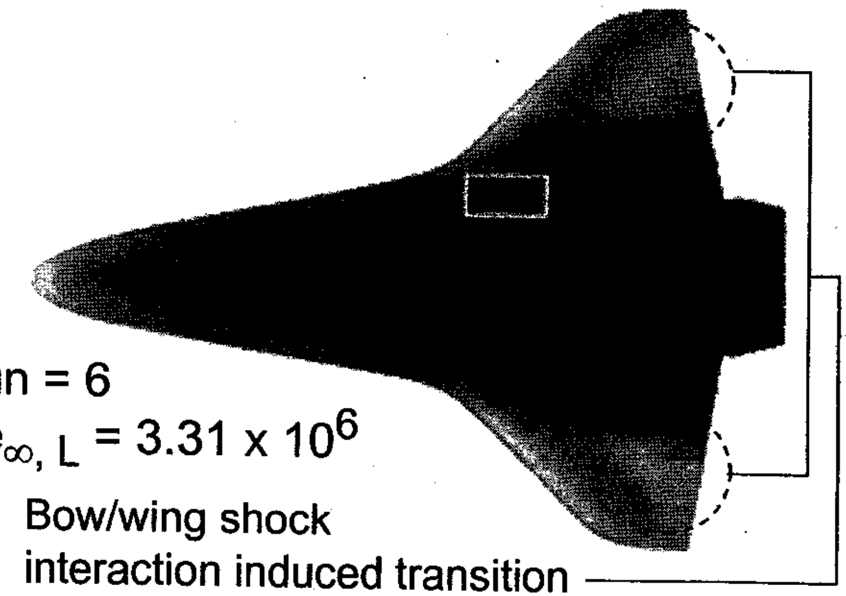




Run = 2
$Re_{\infty,L} = 1.75 \times 10^6$



Run = 5
$Re_{\infty,L} = 2.42 \times 10^6$



Run = 6
$Re_{\infty,L} = 3.31 \times 10^6$

Bow/wing shock
interaction induced transition

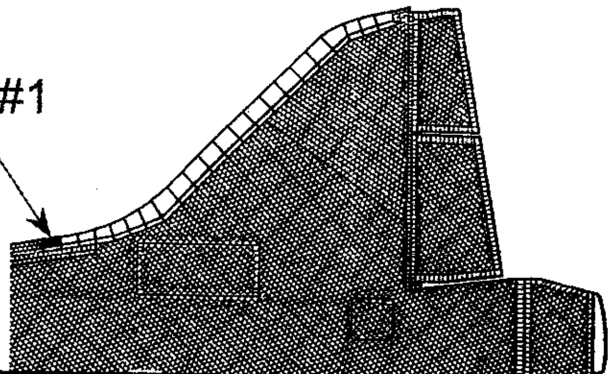
NASA Langley
Aerothermodynamics Branch

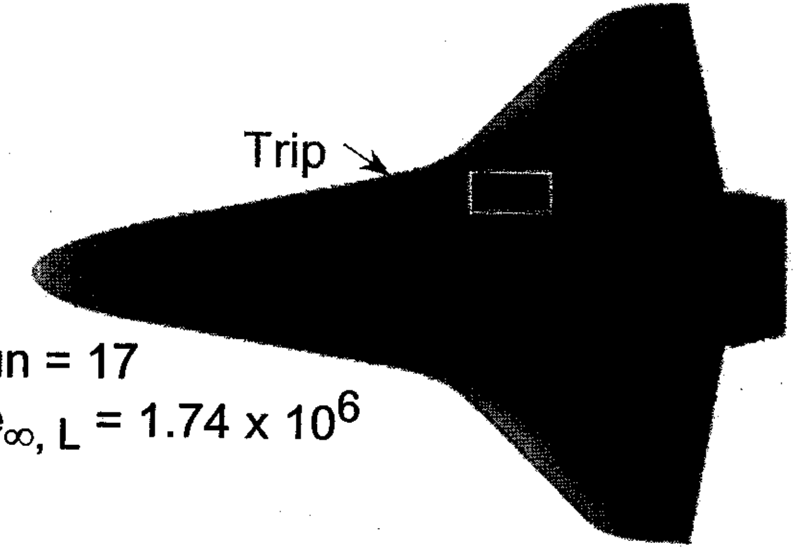
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

NASA LaRC 20-Inch Mach 6 Air

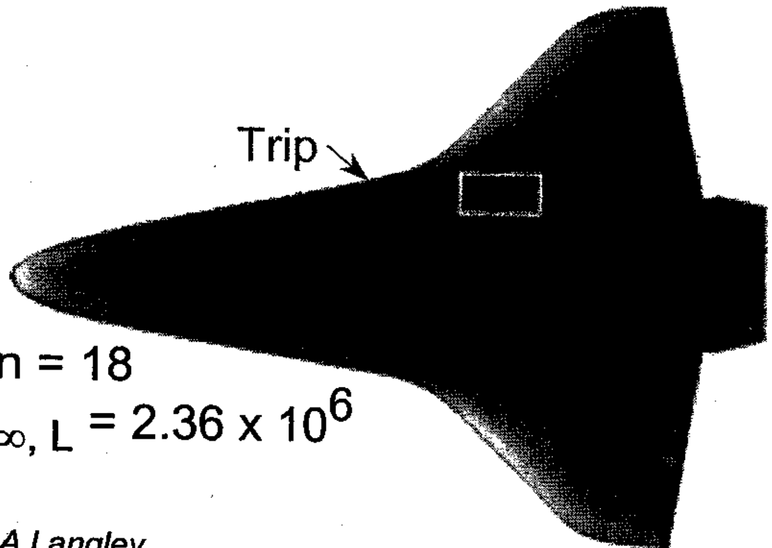
α = 40 deg Panel # 1 0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

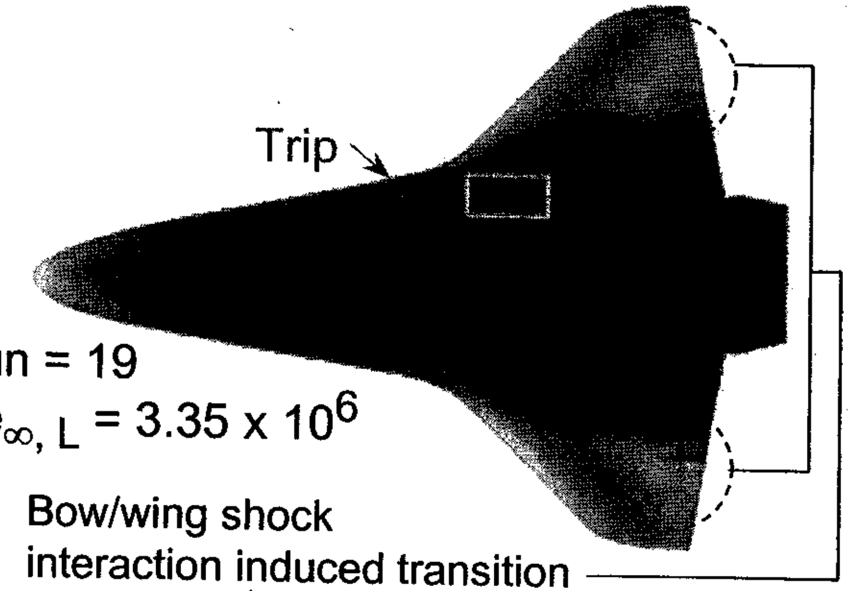




Run = 17
$Re_{\infty, L} = 1.74 \times 10^6$



Run = 18
$Re_{\infty, L} = 2.36 \times 10^6$



Run = 19
$Re_{\infty, L} = 3.35 \times 10^6$

Bow/wing shock interaction induced transition

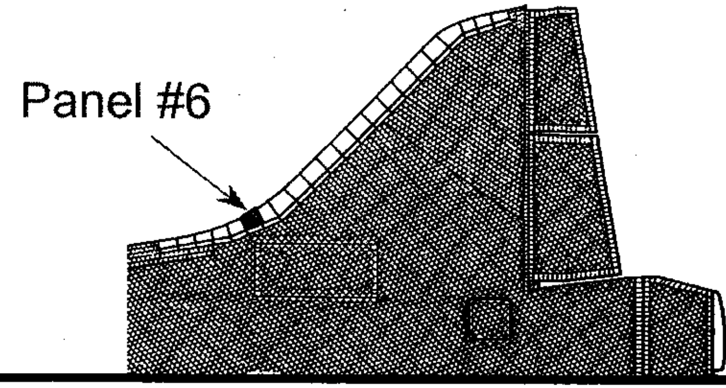
NASA Langley Aerothermodynamics Branch

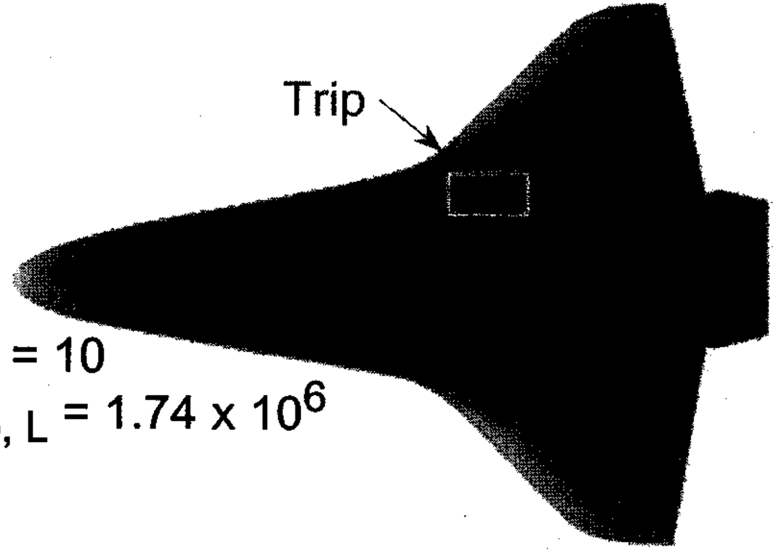
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

NASA LaRC 20-Inch Mach 6 Air

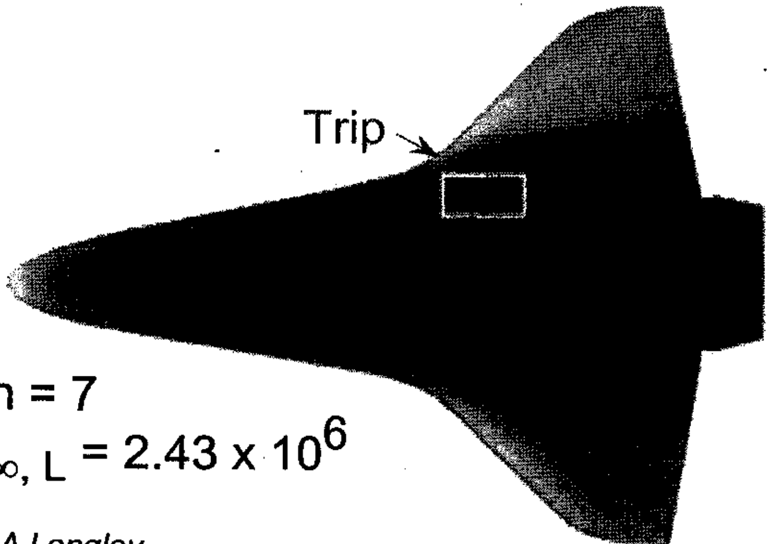
α = 40 deg   Panel # 6   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

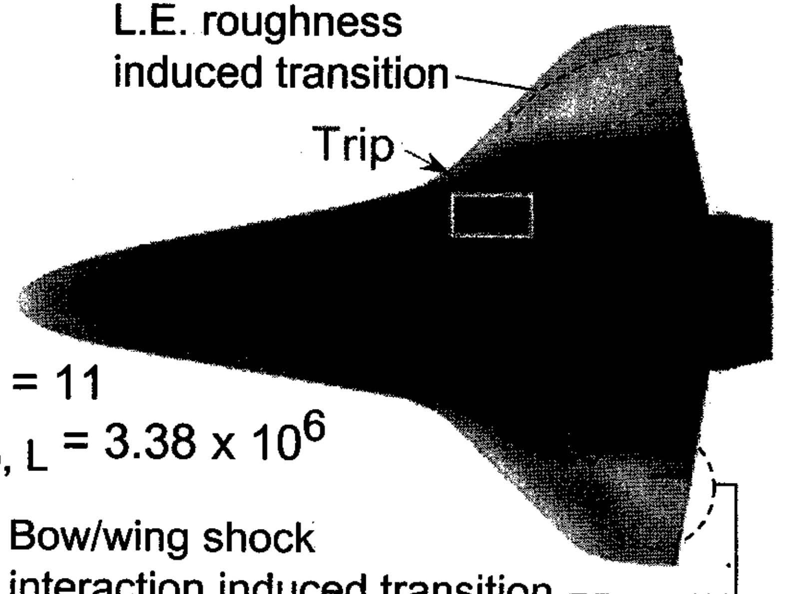




Run = 10
$Re_{\infty, L} = 1.74 \times 10^6$



Run = 7
$Re_{\infty, L} = 2.43 \times 10^6$



Run = 11
$Re_{\infty, L} = 3.38 \times 10^6$

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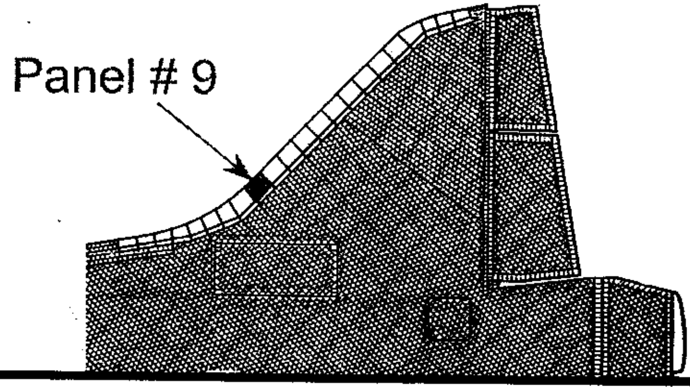
Aerothermodynamics Branch

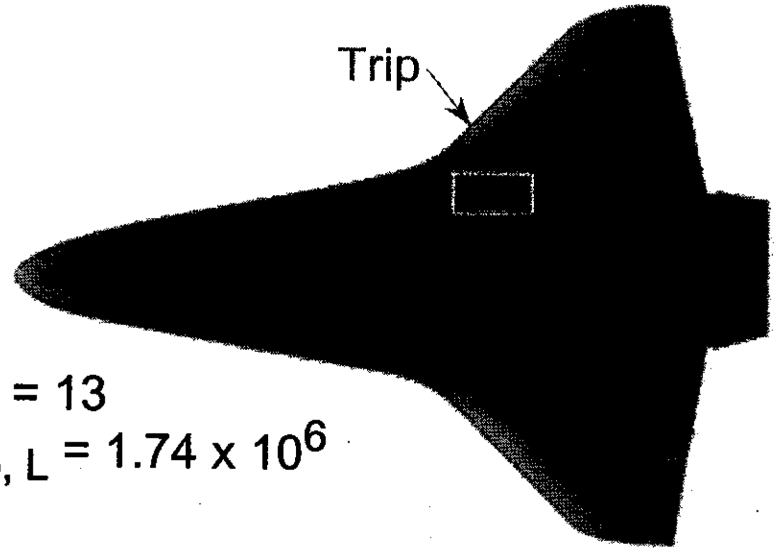
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

NASA LaRC 20-Inch Mach 6 Air

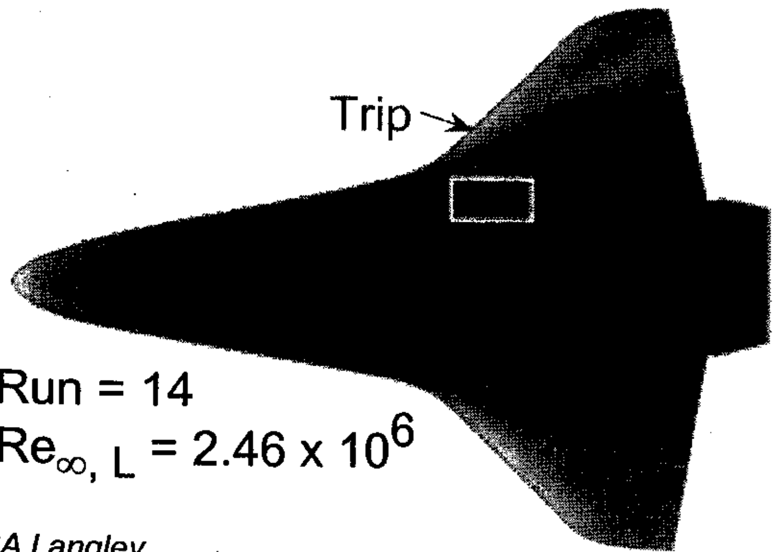
α = 40 deg   Panel # 9   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

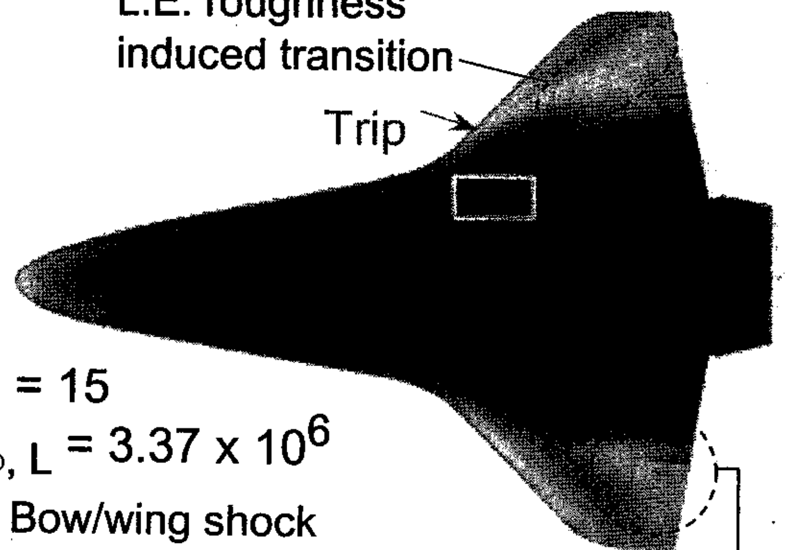




Run = 13
$Re_{\infty, L} = 1.74 \times 10^6$



Run = 14
$Re_{\infty, L} = 2.46 \times 10^6$



Run = 15
$Re_{\infty, L} = 3.37 \times 10^6$

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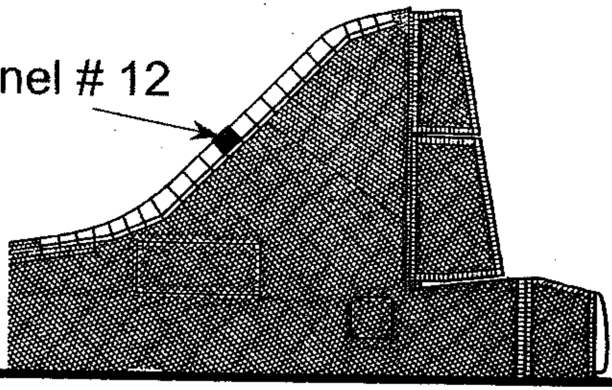
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

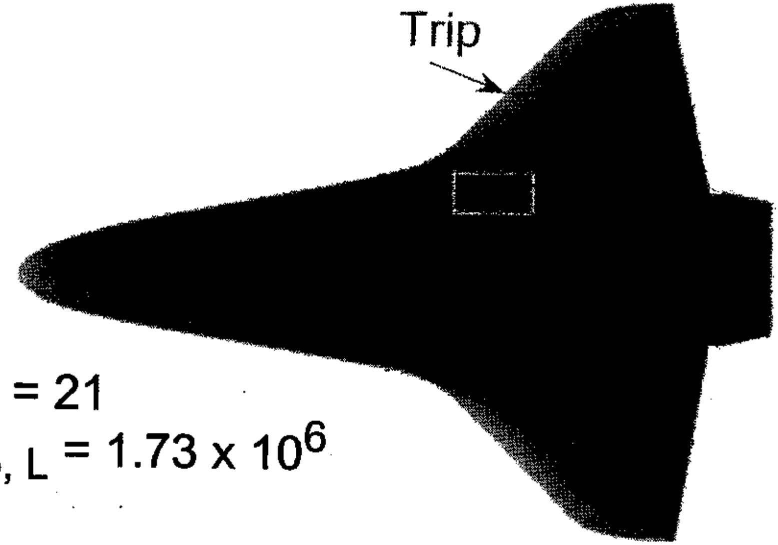
NASA LaRC 20-Inch Mach 6 Air

α = 40 deg   Panel # 12   0.0075 Scale

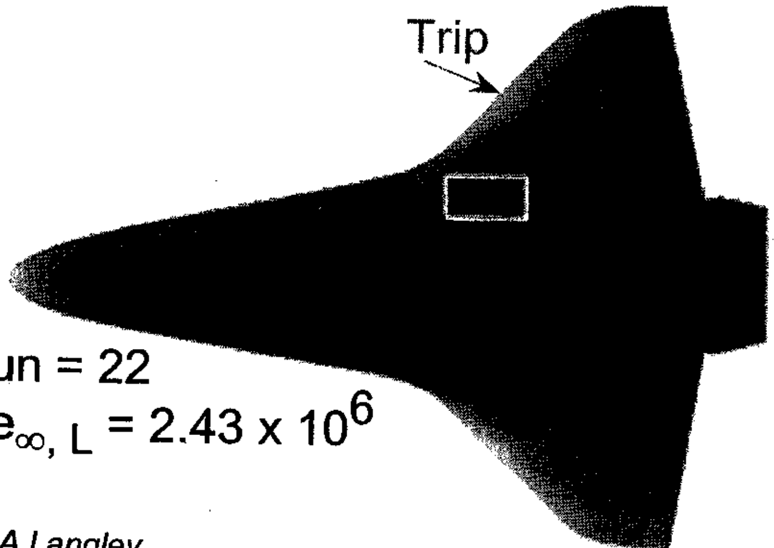
	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

Panel # 12

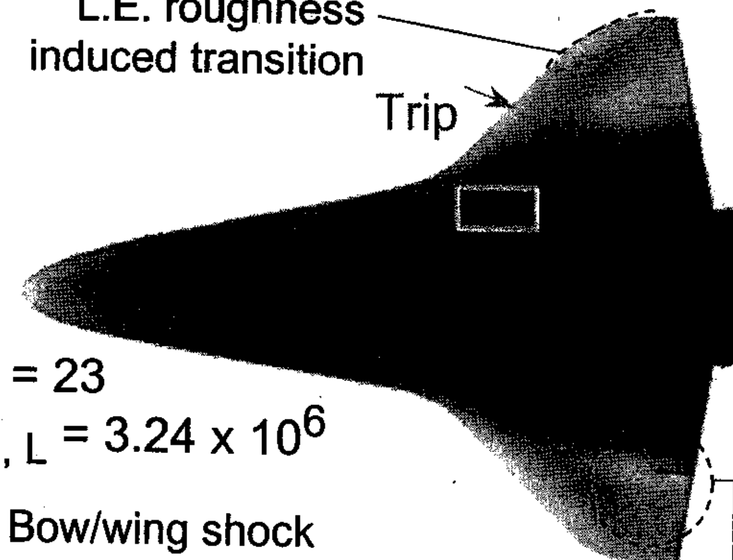




Run = 21
$Re_{\infty, L} = 1.73 \times 10^6$



Run = 22
$Re_{\infty, L} = 2.43 \times 10^6$



Run = 23
$Re_{\infty, L} = 3.24 \times 10^6$

ASA Langley
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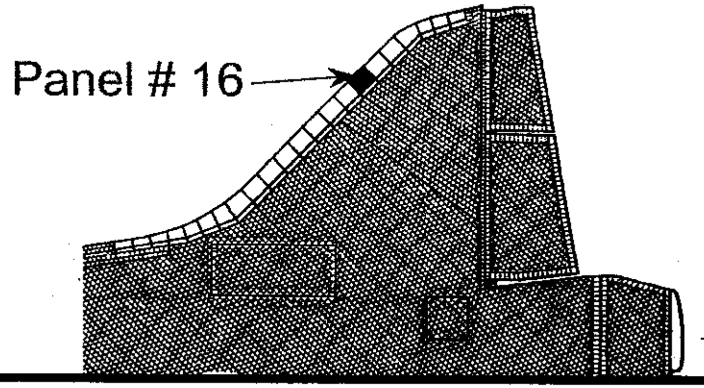
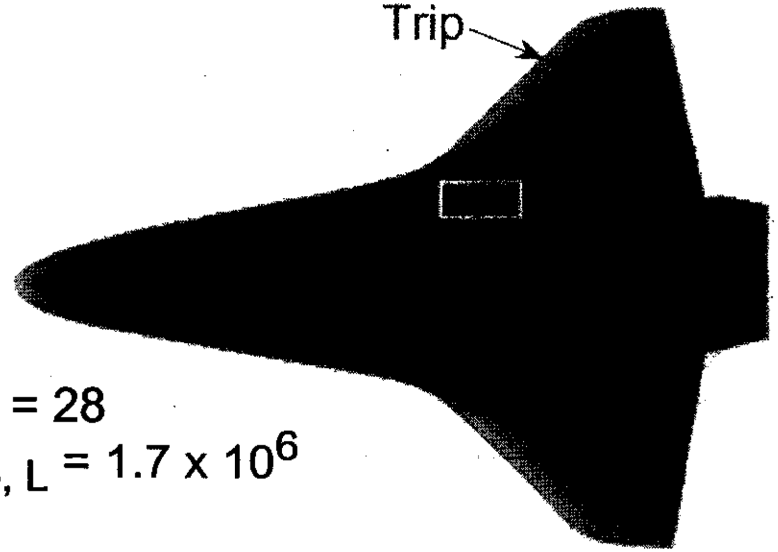
Effect of L.E. Roughness on Orbiter Windward Thermal Mapping

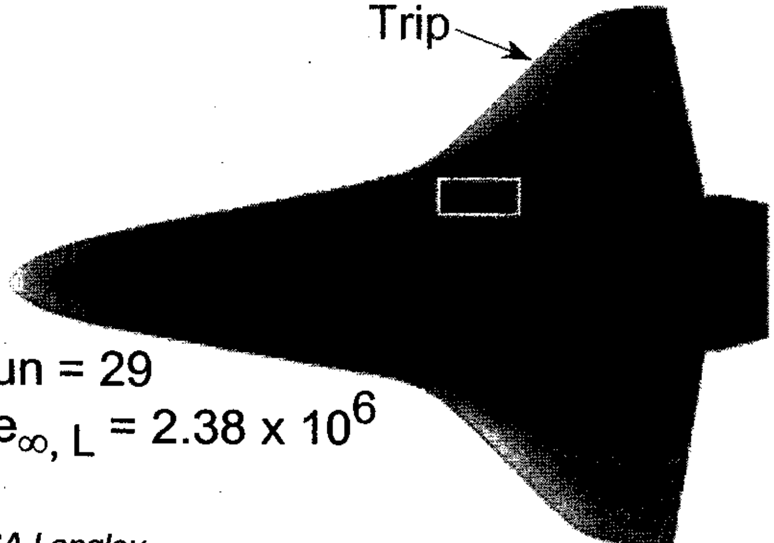
NASA LaRC 20-Inch Mach 6 Air

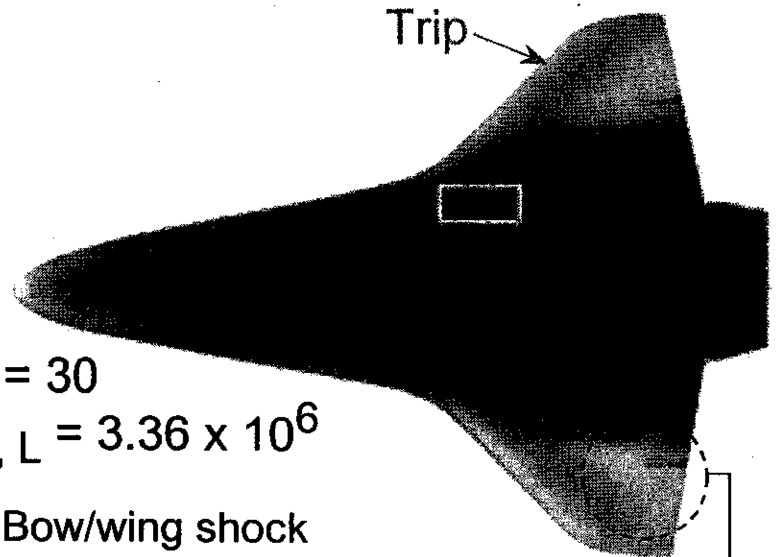
α = 40 deg   Panel # 16   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13









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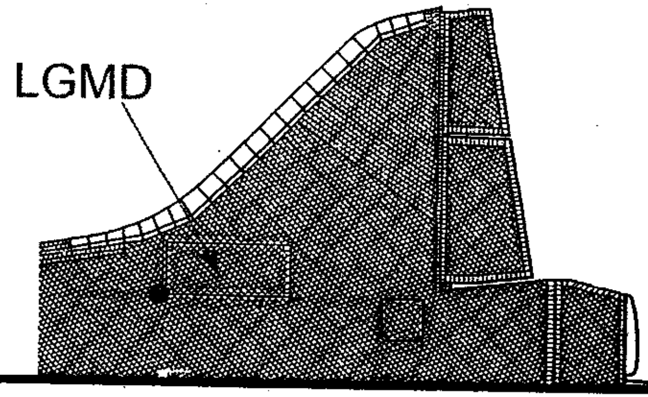
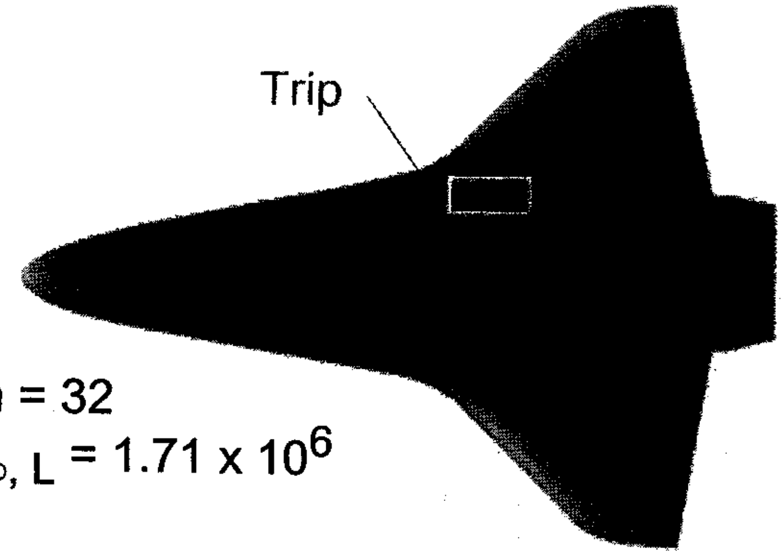
Effect of L.E. Roughness on Orbiter Windward Heating

NASA LaRC 20-Inch Mach 6 Air

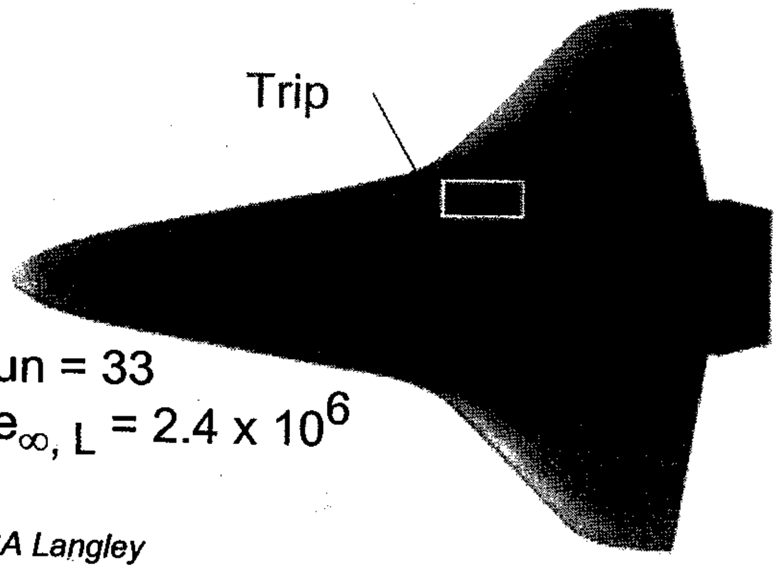
α = 40 deg   Inboard LGMD   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.005x0.005	7x7

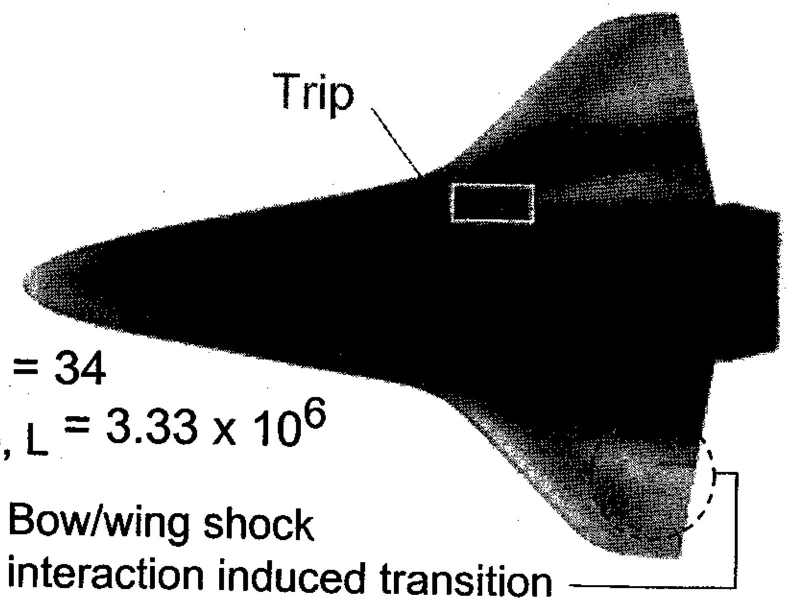




Run = 32
$Re_{\infty, L} = 1.71 \times 10^6$



Run = 33
$Re_{\infty, L} = 2.4 \times 10^6$



Run = 34
$Re_{\infty, L} = 3.33 \times 10^6$

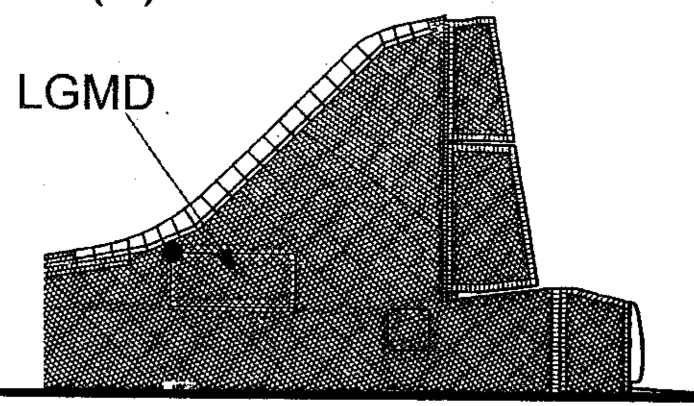
ASA Langley
erothermodynamics Branch

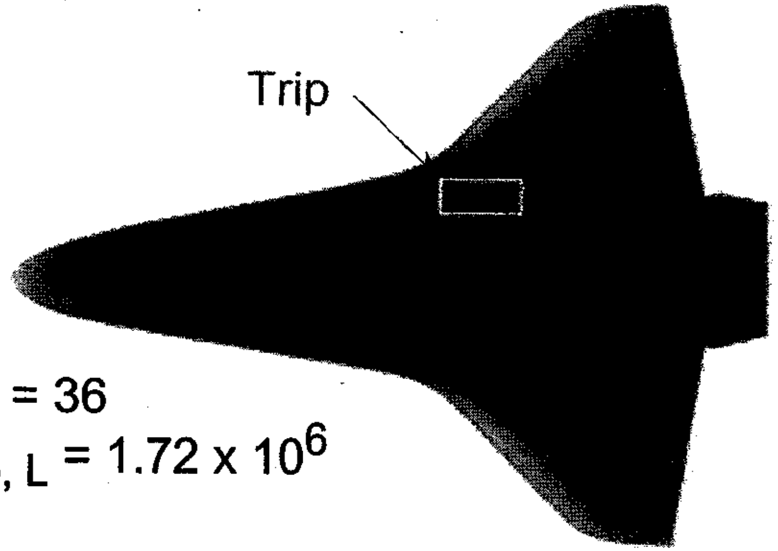
Effect of L.E. Roughness on Orbiter Windward Heating

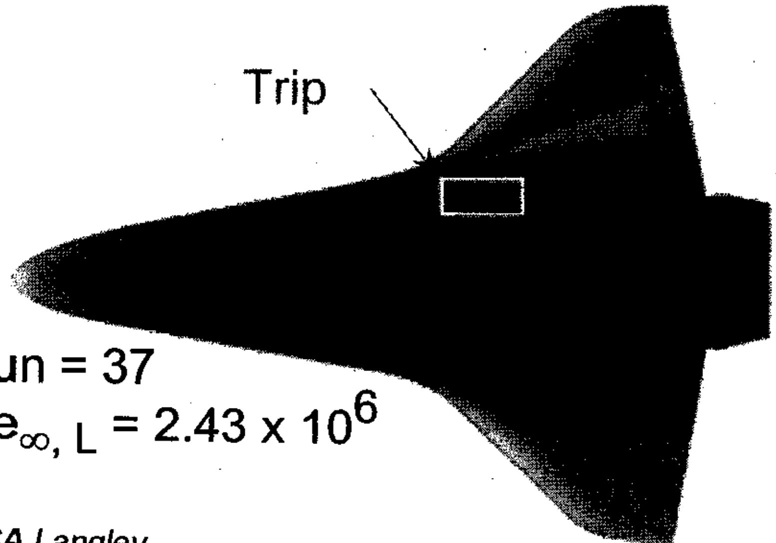
NASA LaRC 20-Inch Mach 6 Air

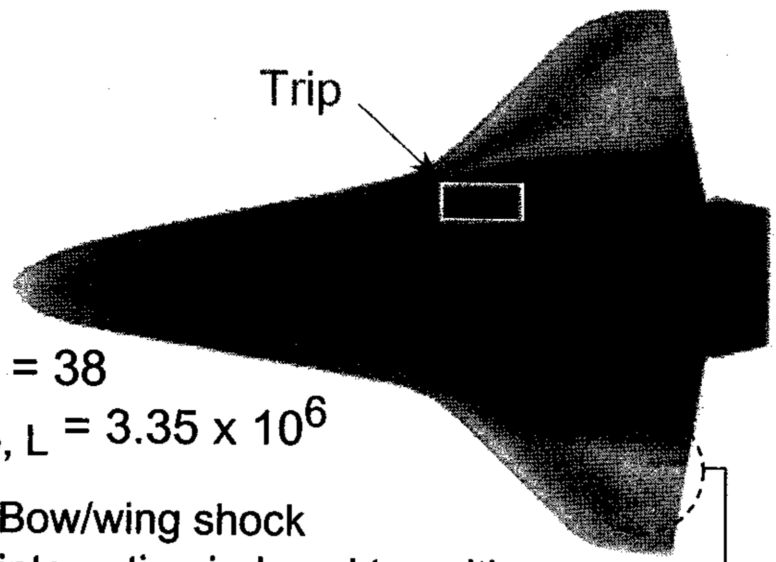
$\alpha = 40$ deg   Outboard LGMD   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.005x0.005	7x7









NASA Langley
Aerothermodynamics Branch

Effect of L.E. Roughness on Orbiter Windward Nondimensional Heating

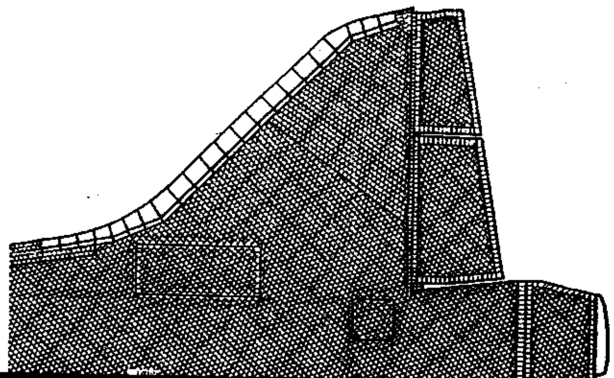
NASA LaRC 20-Inch Mach 6 Air

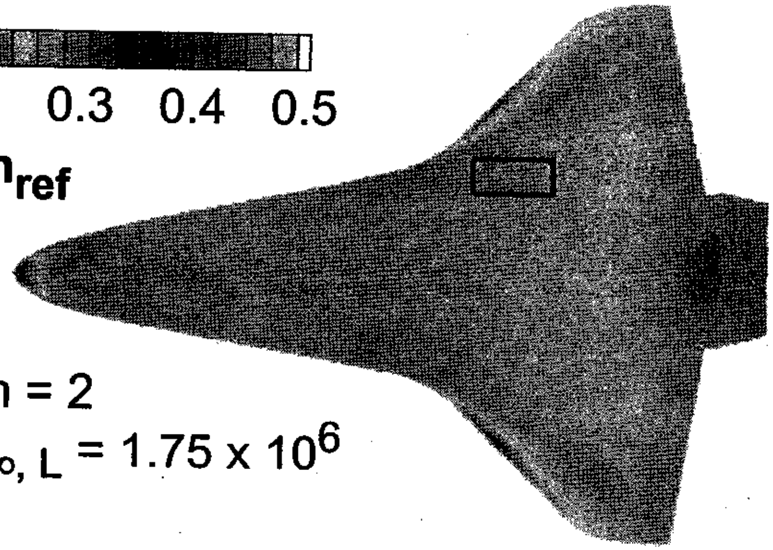
α = 40 deg   Baseline   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

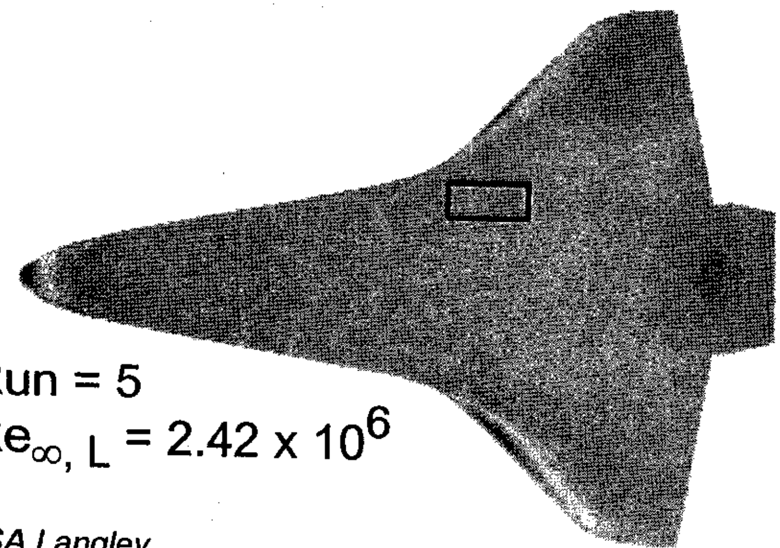
0 0.1 0.2 0.3 0.4 0.5

h/h_{ref}

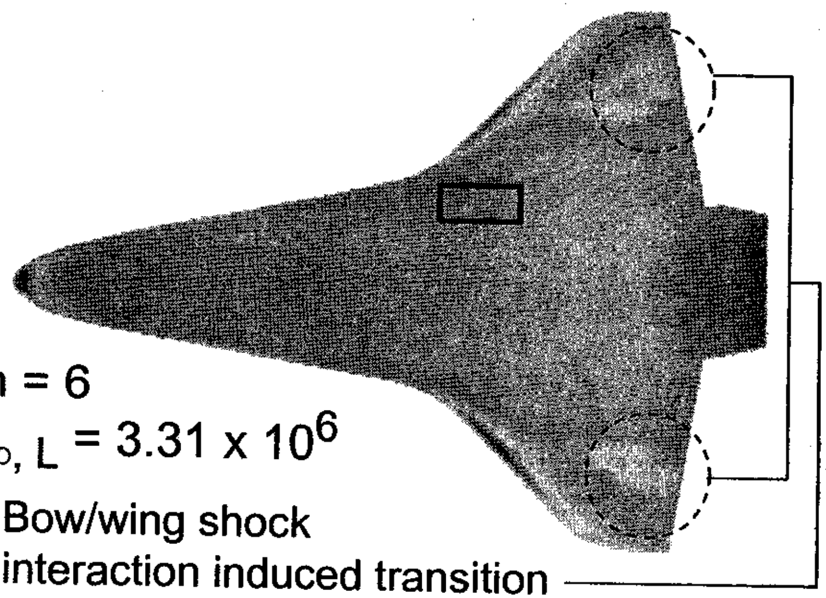




Run = 2
$Re_{\infty, L} = 1.75 \times 10^6$



Run = 5
$Re_{\infty, L} = 2.42 \times 10^6$



Run = 6
$Re_{\infty, L} = 3.31 \times 10^6$

Bow/wing shock
interaction induced transition

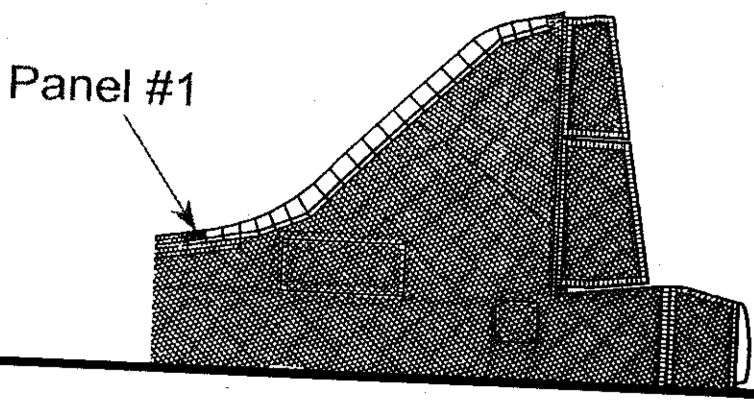
NASA Langley
Aerothermodynamics Branch

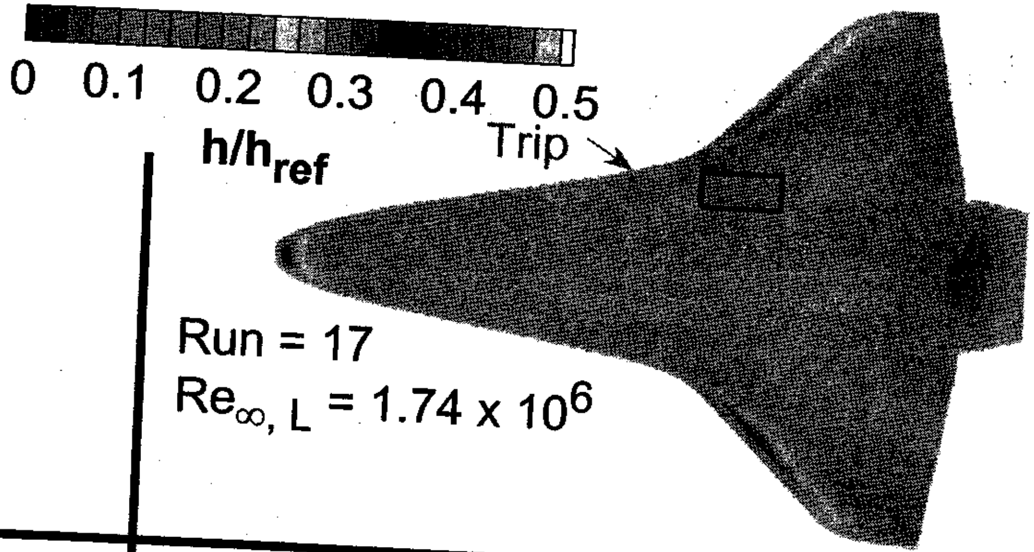
Effect of L.E. Roughness on Orbiter Windward Nondimensional Heating

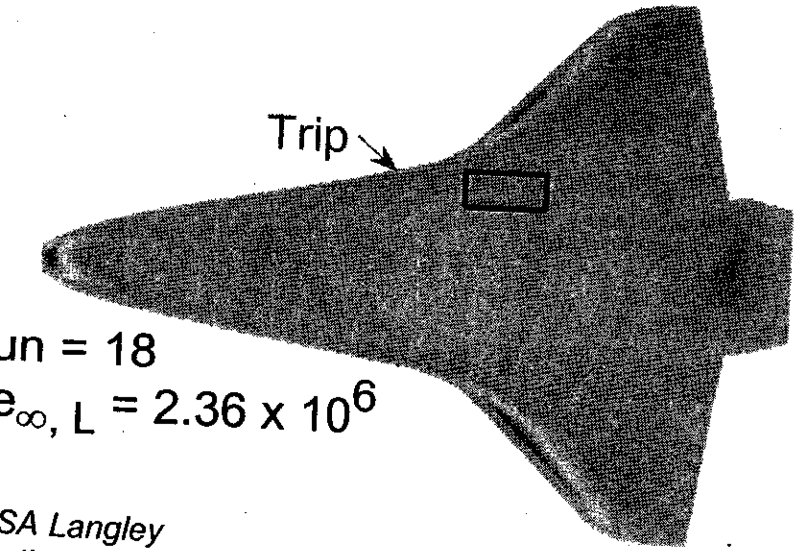
NASA LaRC 20-Inch Mach 6 Air

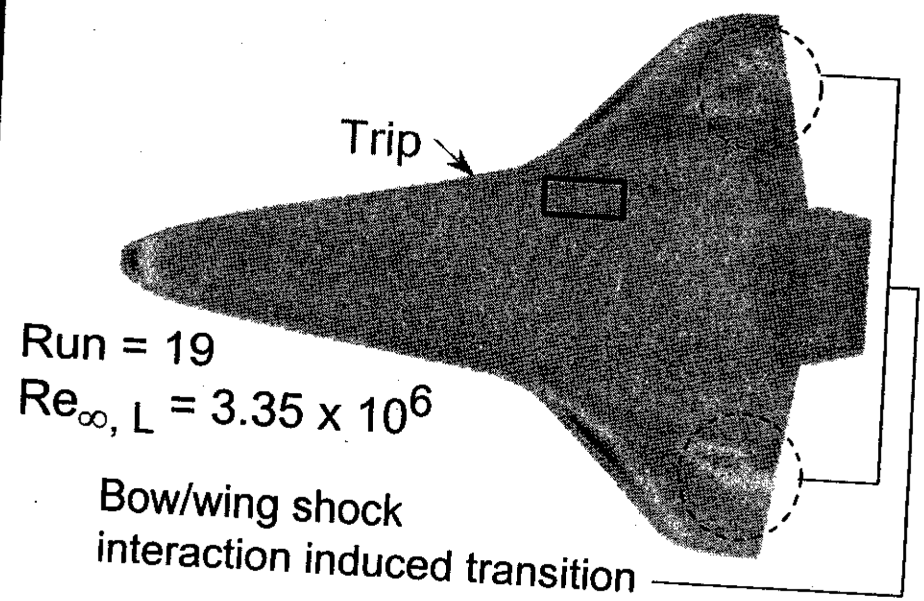
α = 40 deg   Panel # 1   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13









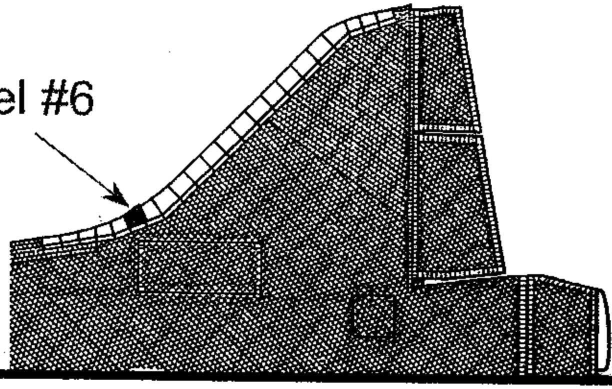
SA Langley
othermodynamics Branch

Effect of L.E. Roughness on Orbiter Windward Nondimensional Heating

NASA LaRC 20-Inch Mach 6 Air

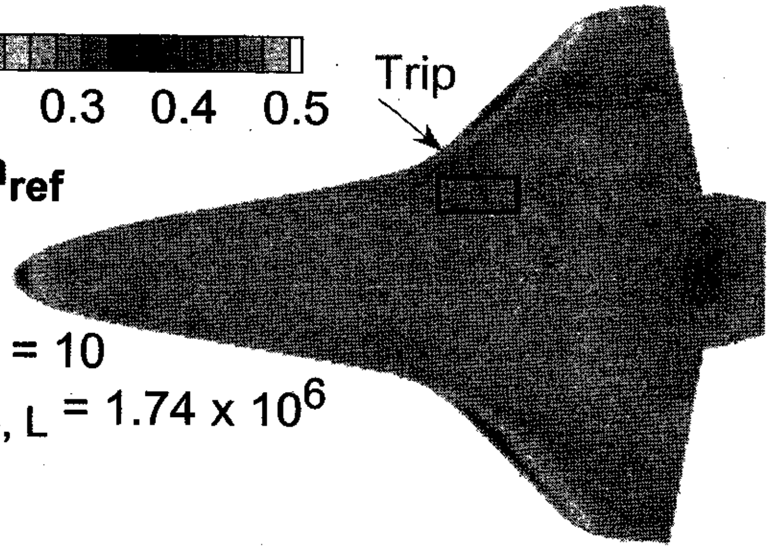
α = 40 deg   Panel # 6   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

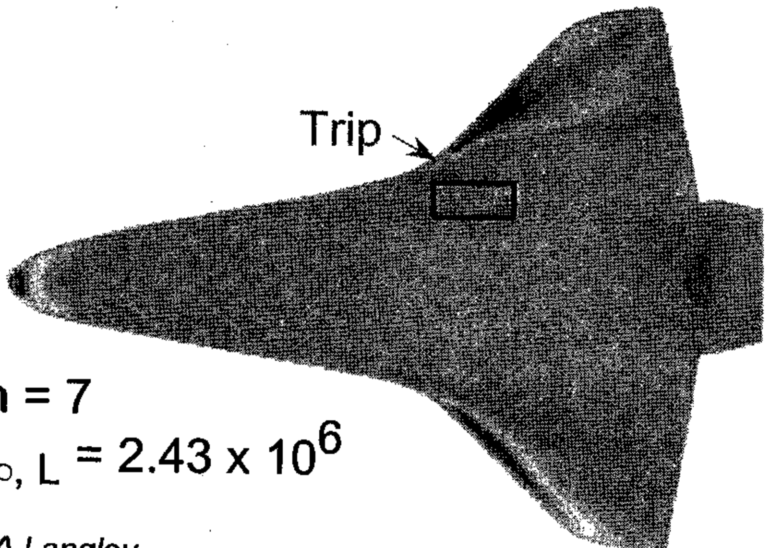


0 0.1 0.2 0.3 0.4 0.5

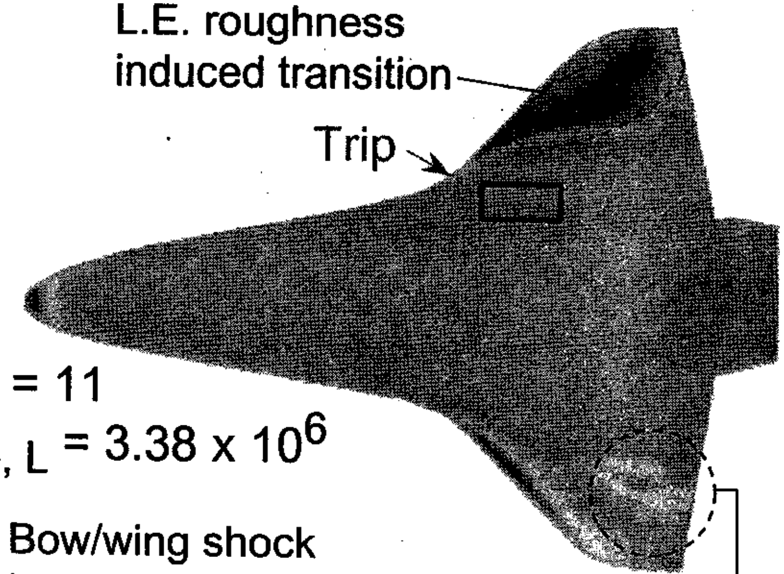
h/h_{ref}



Run = 10
$Re_{\infty, L} = 1.74 \times 10^6$



Run = 7
$Re_{\infty, L} = 2.43 \times 10^6$



Run = 11
$Re_{\infty, L} = 3.38 \times 10^6$

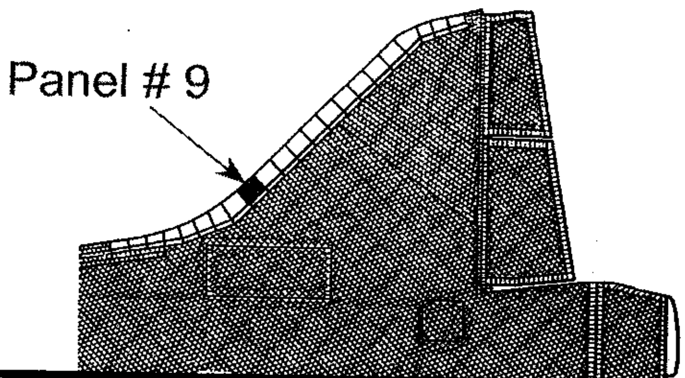
NASA Langley Aerothermodynamics Branch

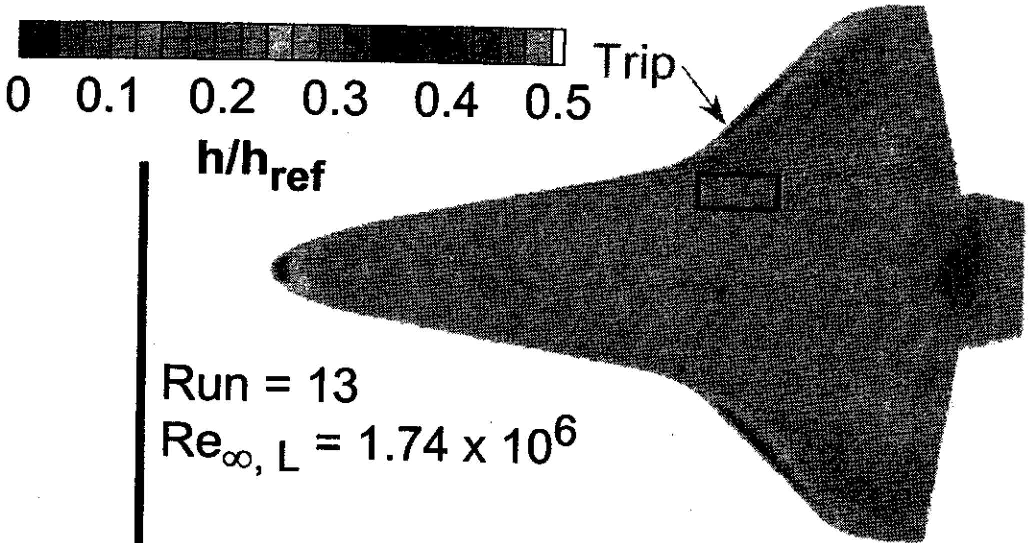
Effect of L.E. Roughness on Orbiter Windward Nondimensional Heating

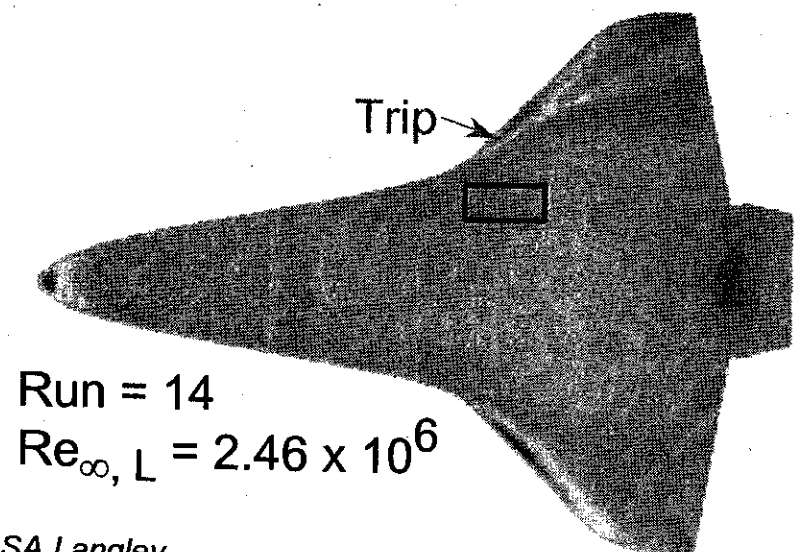
NASA LaRC 20-Inch Mach 6 Air

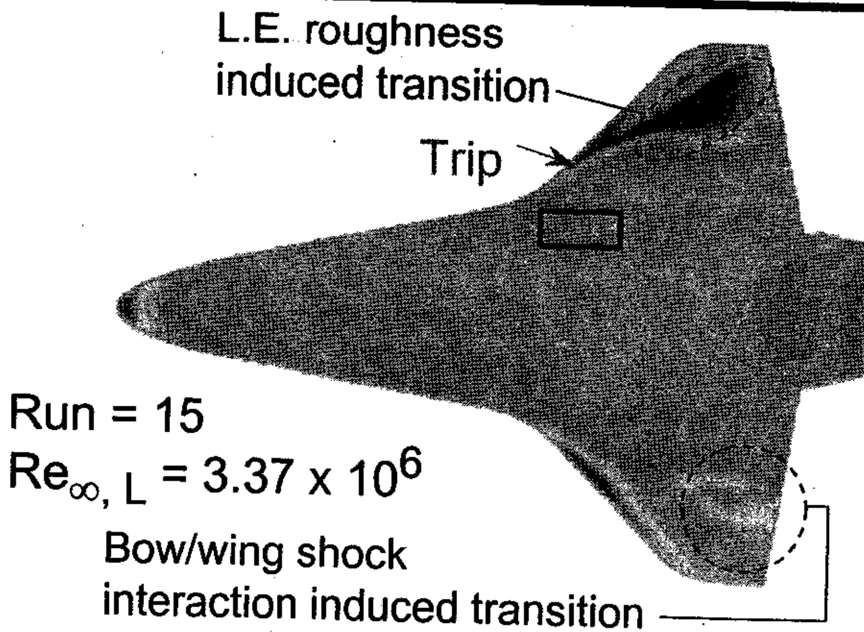
α = 40 deg   Panel # 9   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13









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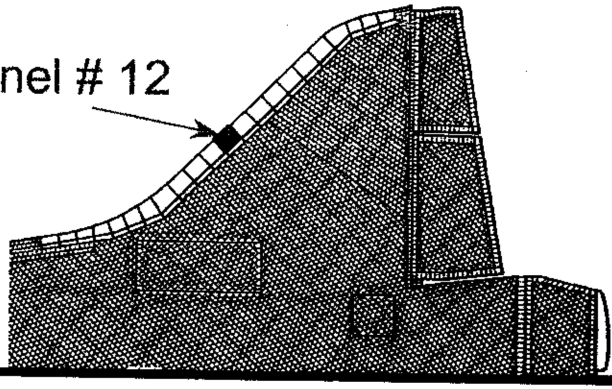
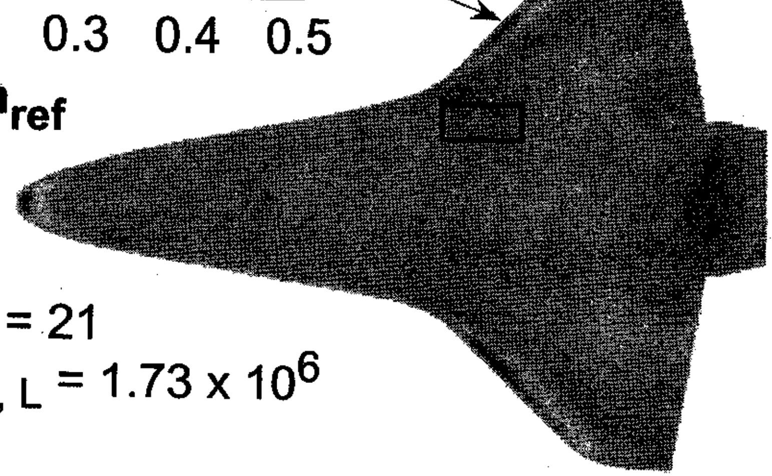
Effect of L.E. Roughness on Orbiter Windward Nondimensional Heating

NASA LaRC 20-Inch Mach 6 Air

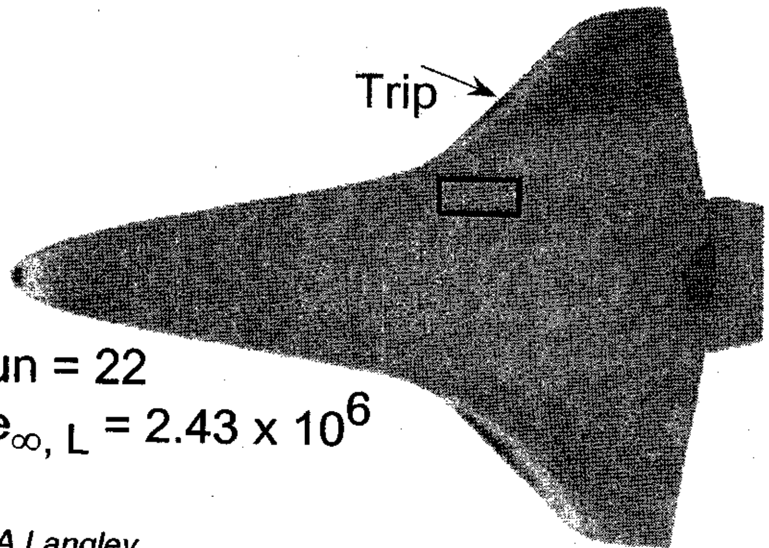
α = 40 deg   Panel # 12   0.0075 Scale

	Model	FS
Trip height (in)	0.0035	0.47
Trip size (in)	0.1x0.1	13x13

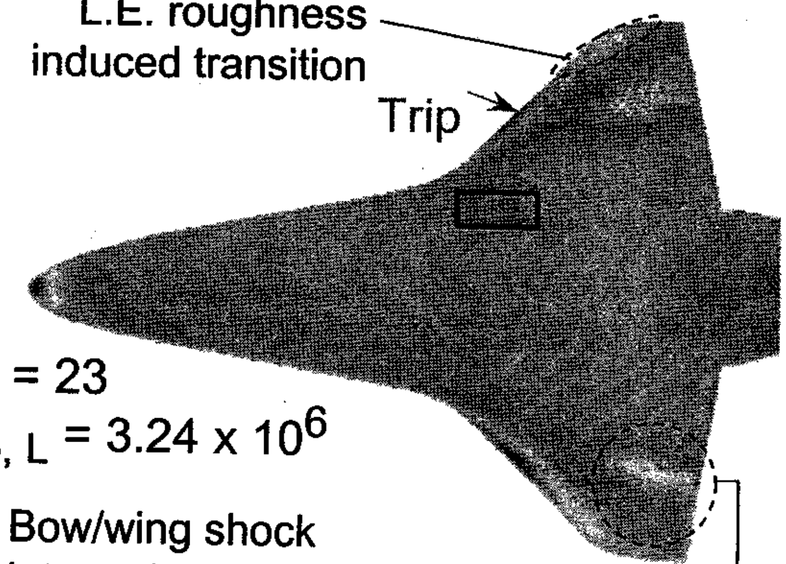




Run = 21
$Re_{\infty, L} = 1.73 \times 10^6$



Run = 22
$Re_{\infty, L} = 2.43 \times 10^6$



Run = 23
$Re_{\infty, L} = 3.24 \times 10^6$

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