Observations, Ideas, and Opinions

Systems Engineering and Integration for Return to Flight

George K. Gafka

Project Management Challenge Conference

March, 2006

Observations, Ideas, and Opinions

- **Upfront Disclaimer #1**
  - **Material transmitted in this presentation may not represent the opinion or policy of NASA!**
- **Upfront Disclaimer #2**
  - **Presenter is conveying some very contextual examples of personal experiences which are not meant to be interpreted as the absolute truth or the right answer for everyone or every situation!**

Process/digest the material as you see fit and decide what may be worth taking away.

Observations, Ideas, and Opinions
Presentation Outline

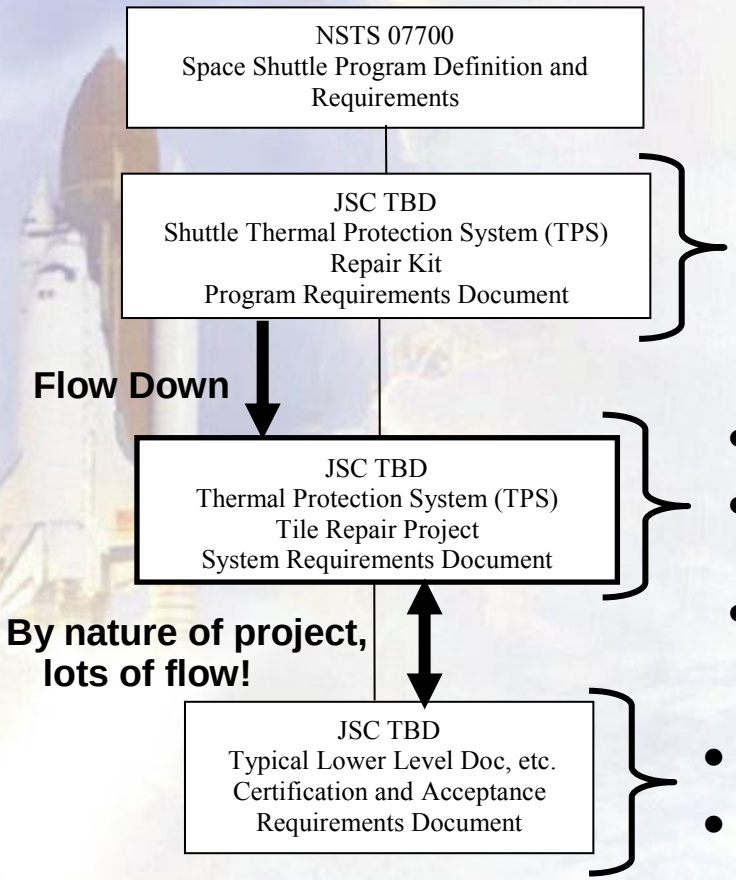
You are here.

- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

In The Beginning…
Project Documentation Philosophy

Thermal Protection System (TPS) Tile Repair Project
Documentation Tree

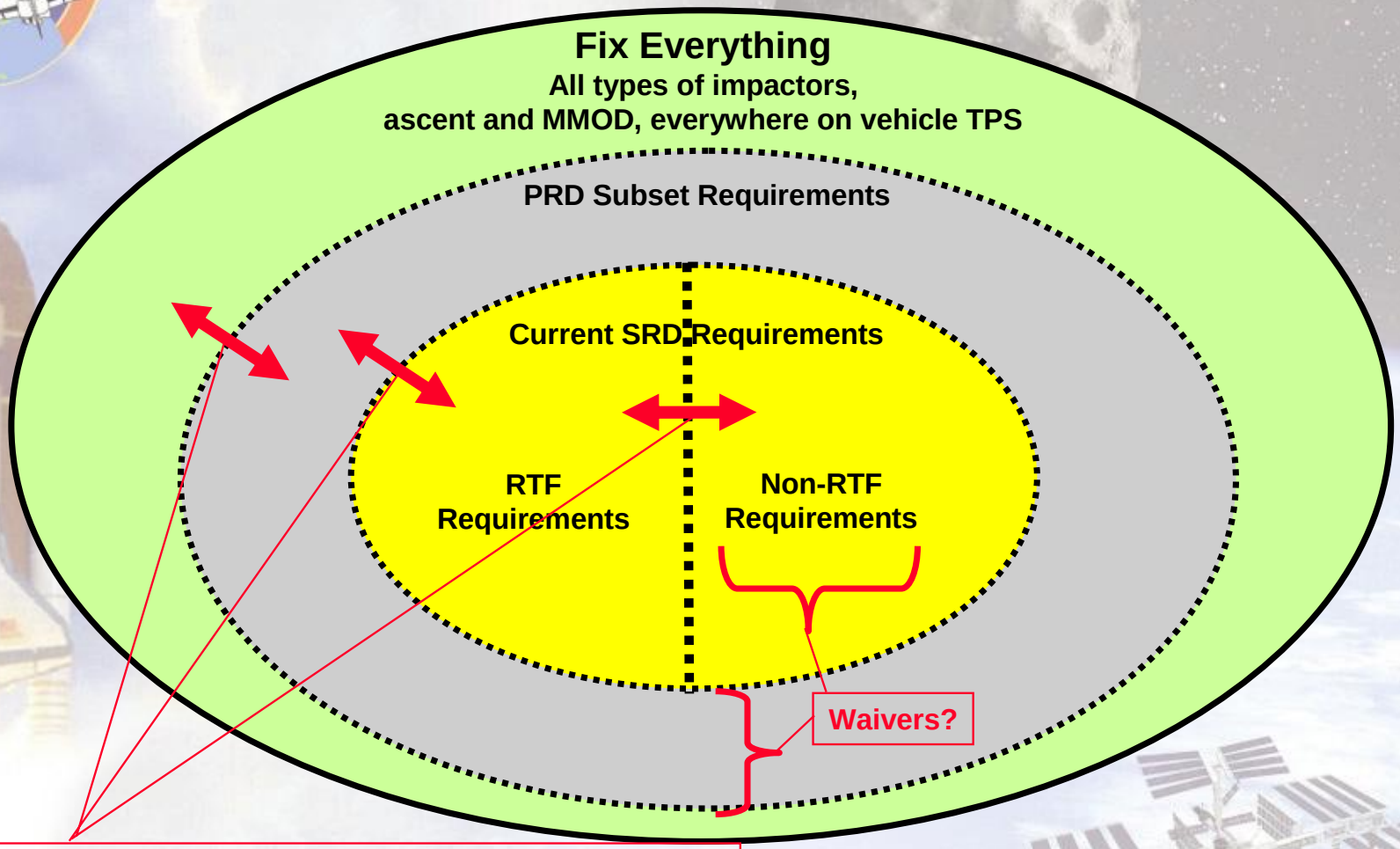


- **Should convey need for Tile Repair Capability. "SRD go figure it out"**
- **Should establish Ground rules for Tile Repair Capability, I.e. criticality, one-time-use, etc.**

- **The "tile repair" shall…**
- **Integrated "capability" performance requirements, both performing the repair and re-entry**
- **Integrated EVA ops/hardware performance**

- **Design-to requirements**
- **Sub-allocations**

REQUIRED Communication with Program Requirements Flow and Philosophy



Who is responsible to set boundary and accept risk?
Who is responsible to substantiate boundary?
MA, MS, MV?

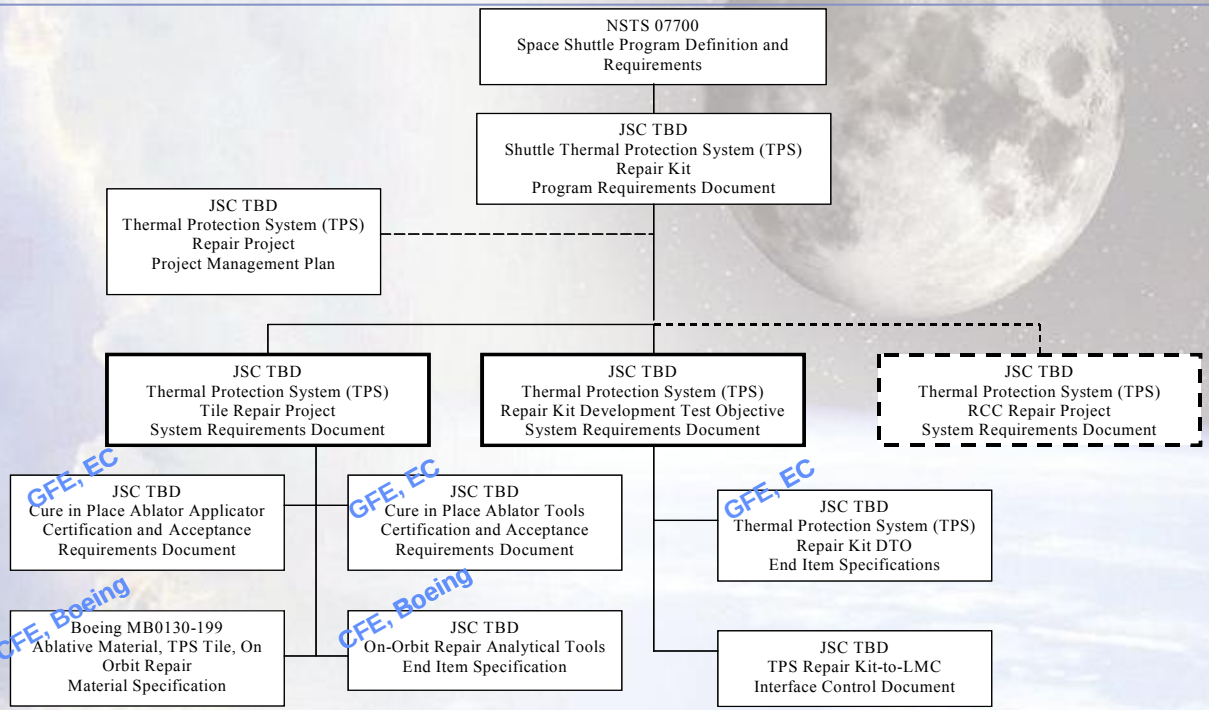
Tile Repair Project RTF Mission

- **Per our revised SRD and Verification Plan, the Tile Repair Project is responsible for delivering the capability to:**
  - Assess tile damage locations and provide near real-time technical rationale to support “Use-as-is” disposition
  - Provide repair materials (qualified vendor), physical tools and operational techniques to conduct a developmental DTO and constitute an emergency tile repair capability if needed
  - Document Limited material and system level test results
- **The Tile Repair Project is responsible for validating the PRD inspection requirements for size of tile damage not requiring inspection by OBSS**
  - 3” for acreage tile
  - 1” for tiles near door penetrations

NOTE: We should think of our “Use-As-Is” capability being comprised of two parts: Analytical Tools & Flight History Database!!!

Planned TRP Deliverables/Documentation

Thermal Protection System (TPS) Tile Repair Project
Documentation Tree



CFE

- "Use-as-is" Analytical Tools (USA/Boe)
  - Cavity Heating Tool
  - Catalytic Heating Tool: Damaged
  - 3D Acreage Tile Thermal Tool
  - Special Config. Thermal Models
  - Tile Stress Tool – RTV Bondline (45 deg)
  - Stress Assessor Tool
- Repair Materials (USA/Boe/LM/OSS)
  - STA-54
  - EW

GFE

- EVA Hardware (JSC EC/XA)
  - EVA Repair Mat'l Aplicators
  - EVA Handtools
- "Use-as-is" Analytical Tools
  - CFD for Cavity Heating: Baseline (Ames)
  - CFD for Cavity Heating: Flt Trace. (Ames)
  - Boundary Layer Transition Predict. (LaRC)

TRP - Roles/Responsibilities
Repair Material

Process Dev.
SE&I IPT

Prod/Logistics IPT
(LM, USA/KSC)

NASA Project
MV, EA, ES, EC

USA
P.O.

Flt 3+ Prod.

NASA
IWTA (GFE)

R&D
Pre-qual testing
Mat'l down-select
Scale-up
System level testing
KC-135 & HTV testing

Boeing
P.O. (CFE)

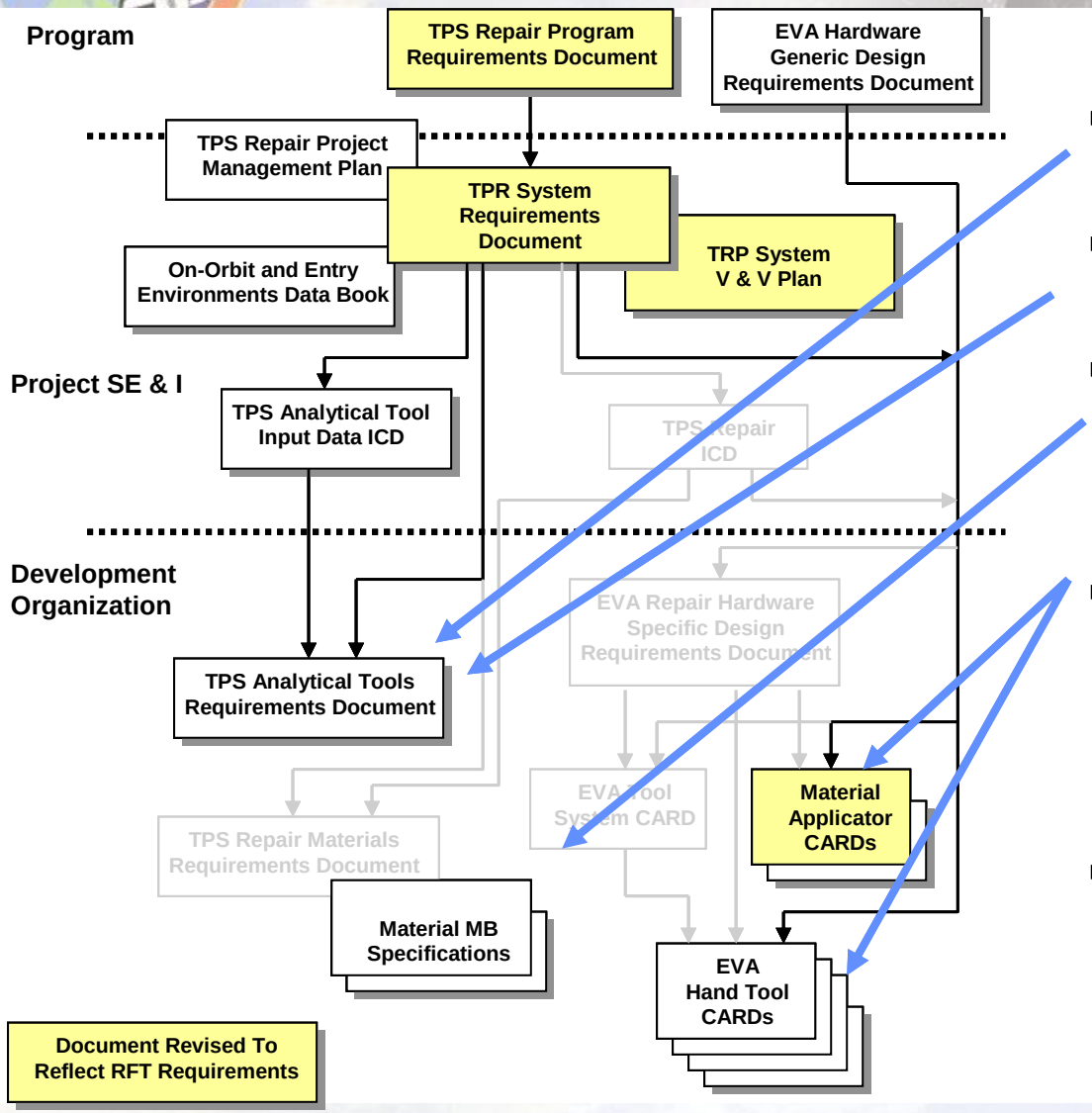
Characterization
Qualification
Verification
HTV-2
Flt 1 & 2 Production

LMSSC -
AO

Material developer
Material provider
Material testing
Tool provider (LMSO)
Mat'l-Canister-Tool C/O

George K. Gafka 281-483-7732

Planned TRP Documentation For RTF



- **Verified analytical tools for damaged acreage tile**
- **Validation of damage size inspection requirement**
- **Repair materials qualified to Material Specifications (physical properties and processes)**
- **EVA tools verified for Crit 3 safety**
- **<u>Limited</u> material and system level test data**

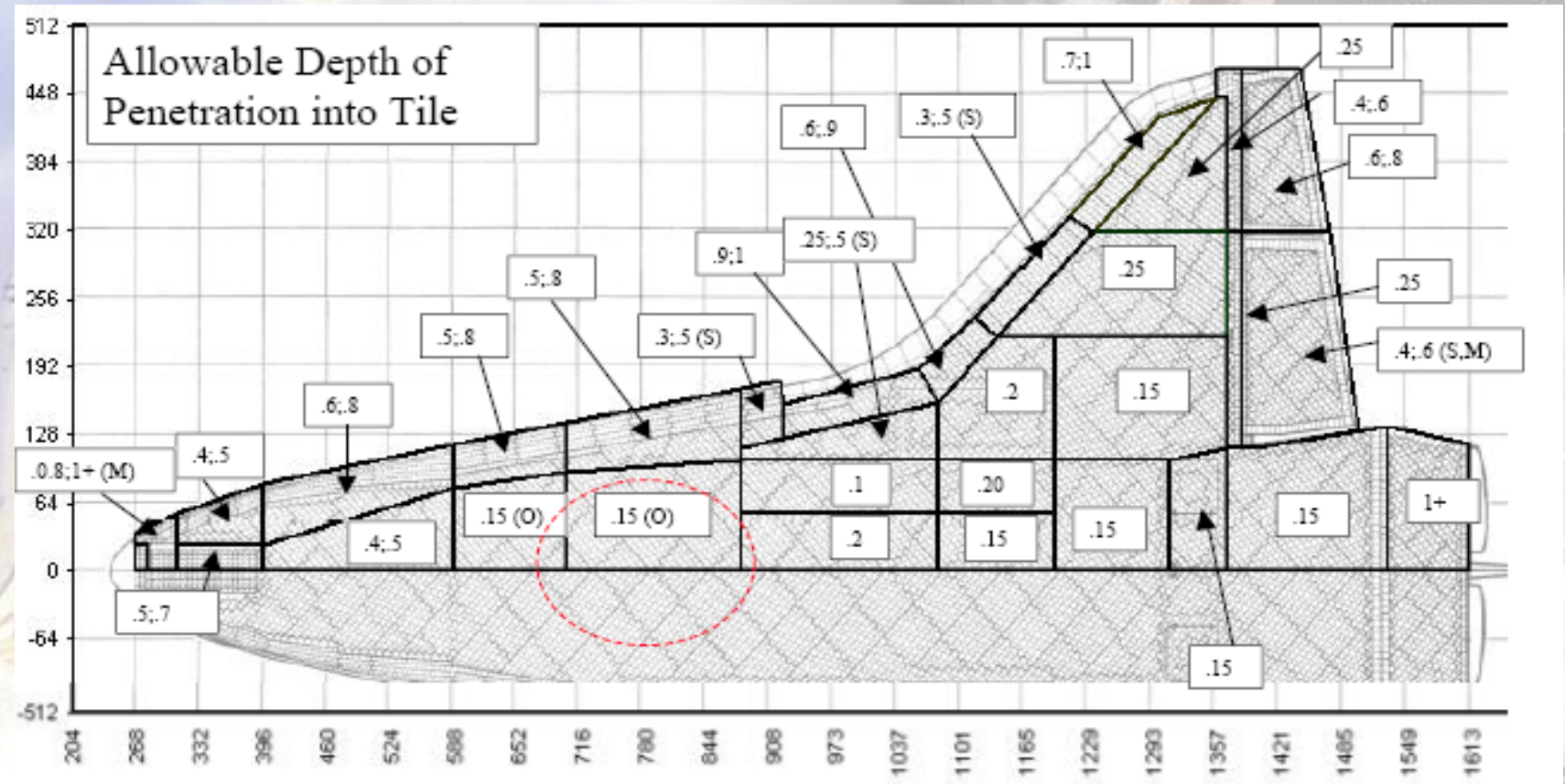
Observations, Ideas, and Opinions
Presentation Outline

You are here.

- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

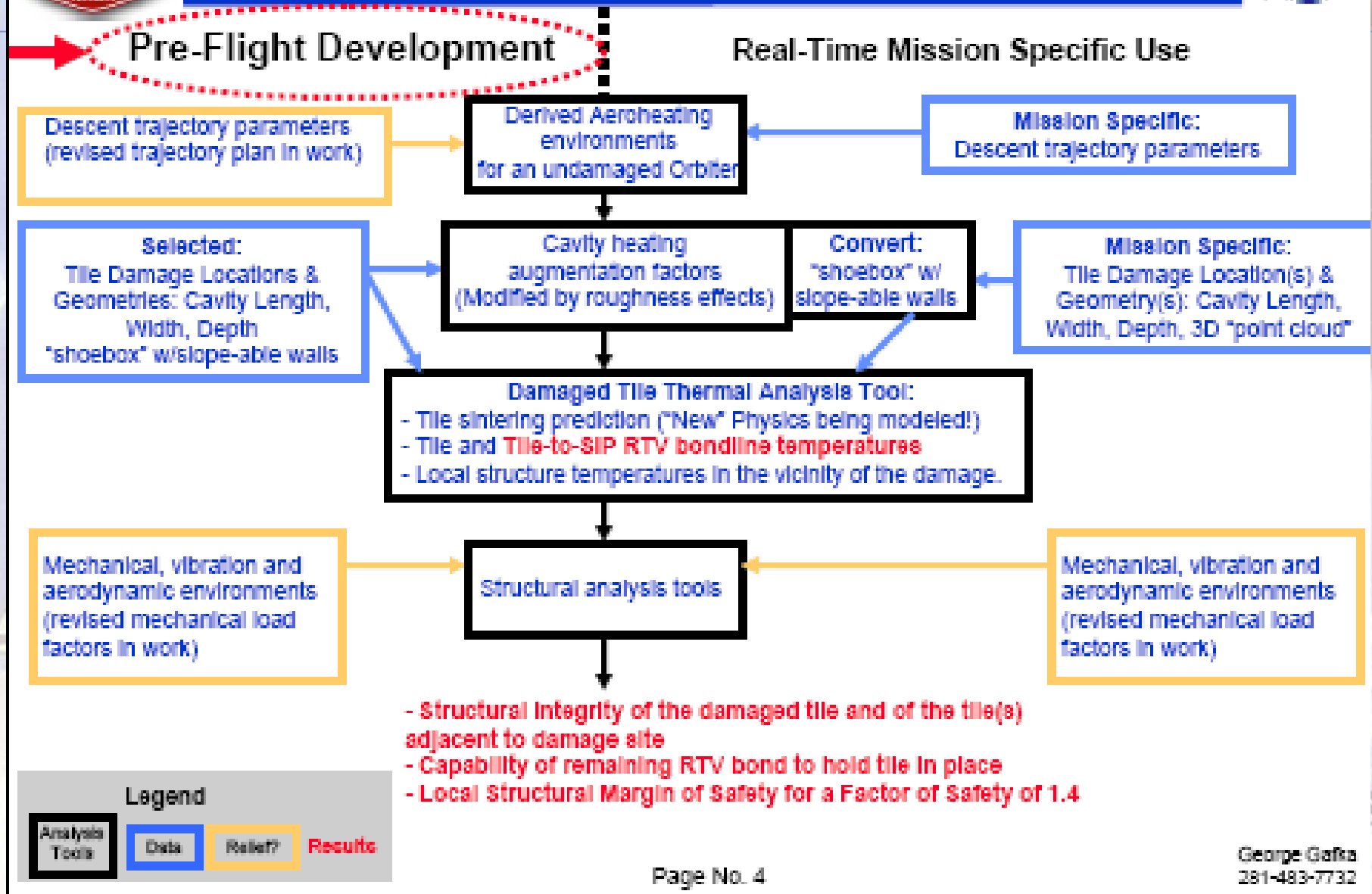
- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

Results to date (early 2005)
Best Estimate of Damage "Map"



Primary failure mode is RTV overtemp. Other modes are structural temperature (S), structural margin (M), and excessive OOPD (O)

Development of TRP "Use-As-Is" Analytical Tools
Development of Inspection Criteria (need for OBSS/depth)

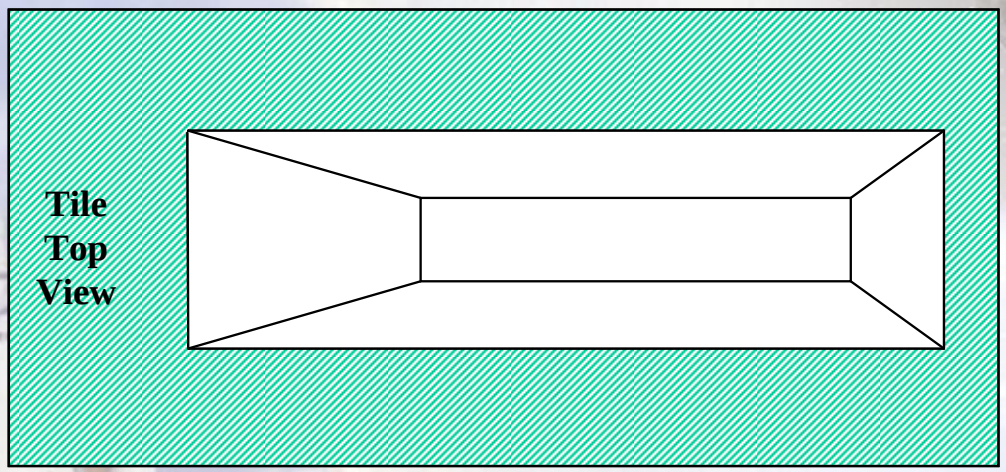


Page No. 4

George Gafka
281-483-7732

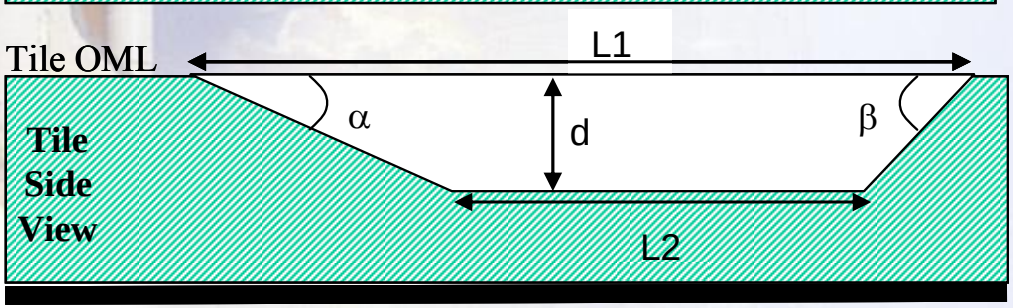
In-Scope Damage Geometries

Flow Direction

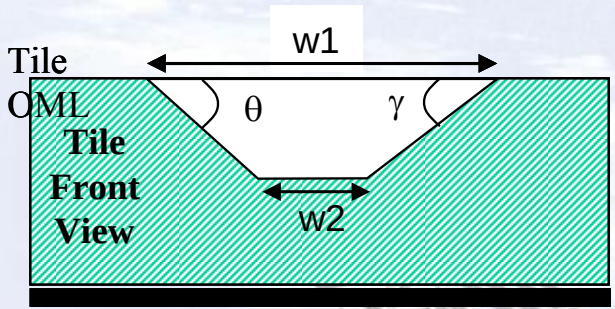


Limitations:

TBD ≤ L1 ≤ 20
TBD ≤ L2 ≤ 20
(L1 ≥ L2)
0.02 ≤ d ≤ full tile
0.25 ≤ w1 ≤ 10
0.25 ≤ w2 ≤ 10
(w1 ≥ w2)
0 ≤ α ≤ 90
0 ≤ β ≤ 90
0 ≤ θ ≤ 90
0 ≤ γ ≤ 90

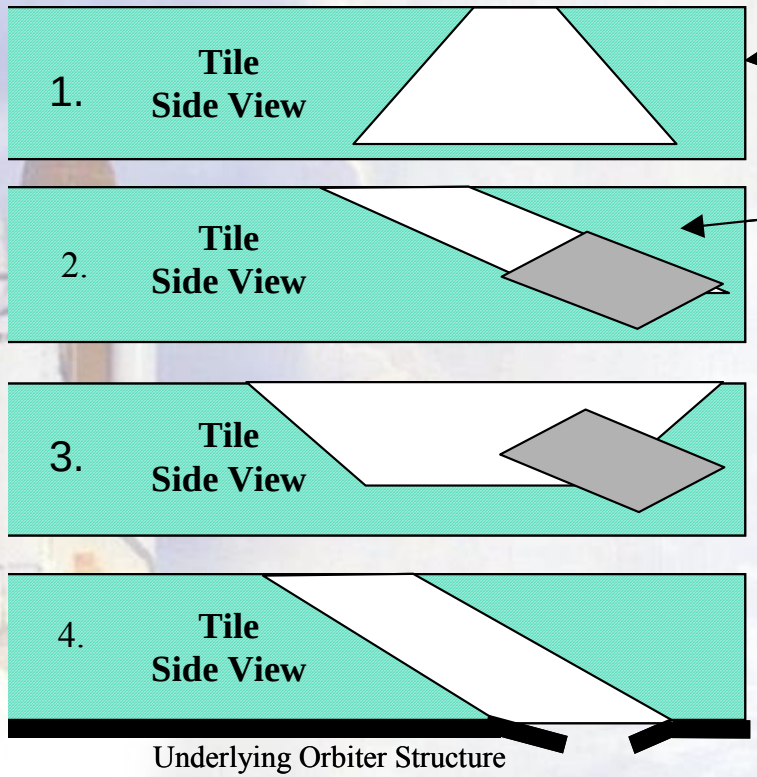


Underlying Orbiter Structure



Underlying Orbiter Structure

Examples of Out-of-Scope Damage Types/Geometries



Damage geometry out-of-scope (w2 > w1, represents damage from certain MMOD impacts)

Damage geometry out-of-scope (β constraint violation, represents damage from certain high density impactors, i.e. ablator material)

And/or

Impactor remaining in cavity

Impactor remaining in cavity

Penetration into structure
(with possible underlying structural damage)

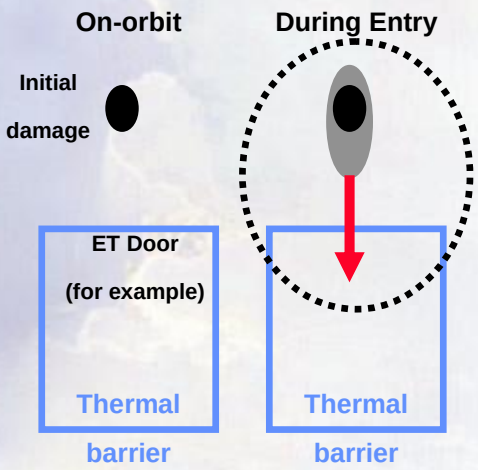
NLGD,MLGD,ETD
Notional Depiction of Capability/Concern

- NOTE: Although 3-D models / analytical tools are being developed for these special penetration areas, there is no current plan to correlate analysis to any test data!
- Penetration flow and understanding response of the thermal barrier is a very complicated scenario

Forward

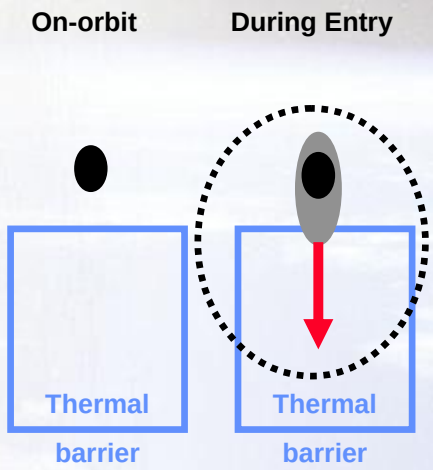
Aft

Scenario 1



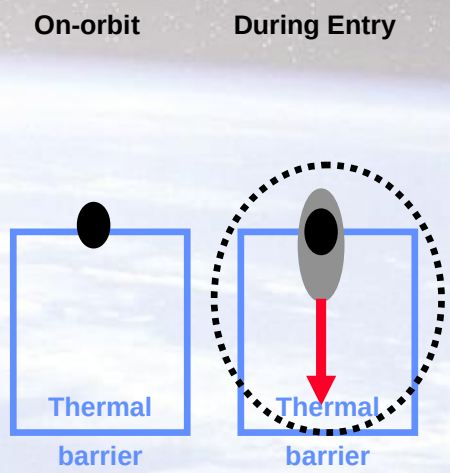
- Assess tile separately
- Assess elevated heating on healthy thermal barrier/seals
- Probably can be dispositioned using currently planned analytical tools

Scenario 2



- Assess tile slumping into thermal barrier/seals
- Elevated downstream heating
- Analytical tools will not be correlated by test data

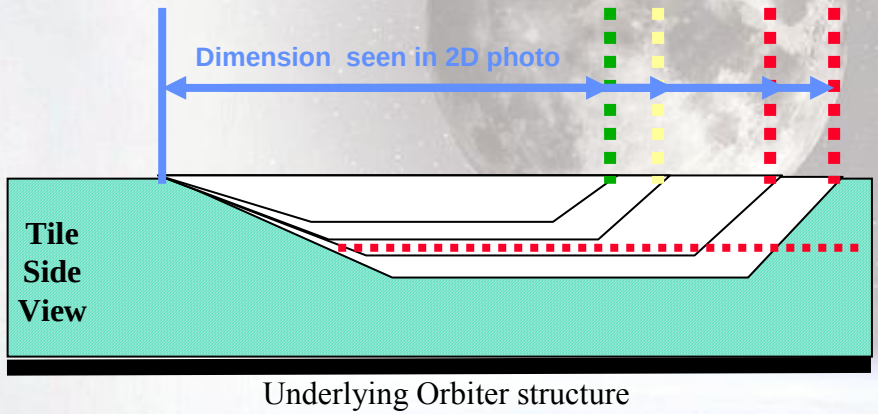
Scenario 3



- Assess tile damage on thermal barrier/seals
- Elevated downstream heating
- Current analytical tools may not be able to model this scenario

Risk of "missing something with only 2D inspection" versus Ops Trade-space result unknown at this time!

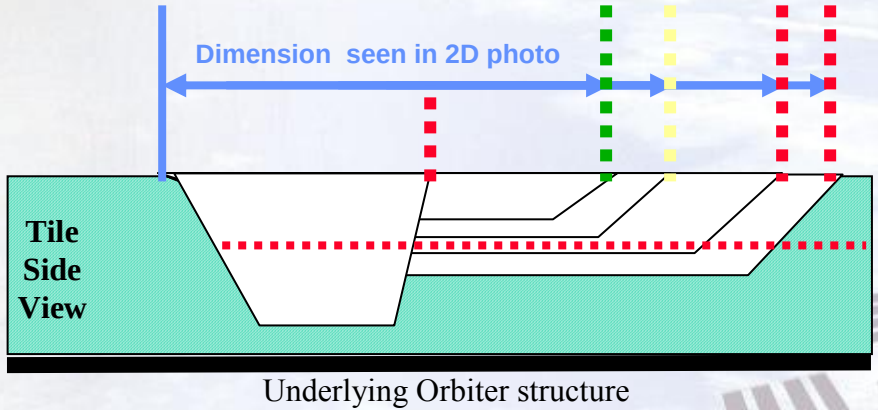
"Standard Gouge"



Depth of damage strong determining factor in threshold for non-conformance determination

"Deep Penetration"

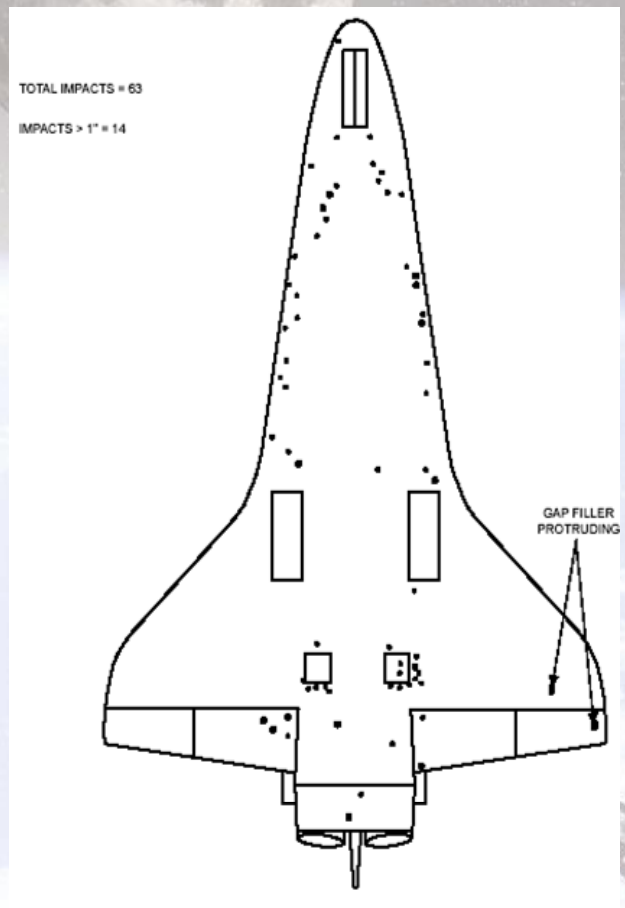
Protecting for this could seriously affects OBSS activities and ops!



Can this occur? How much risk exists for this scenario?

OV-102 Flight Damage History

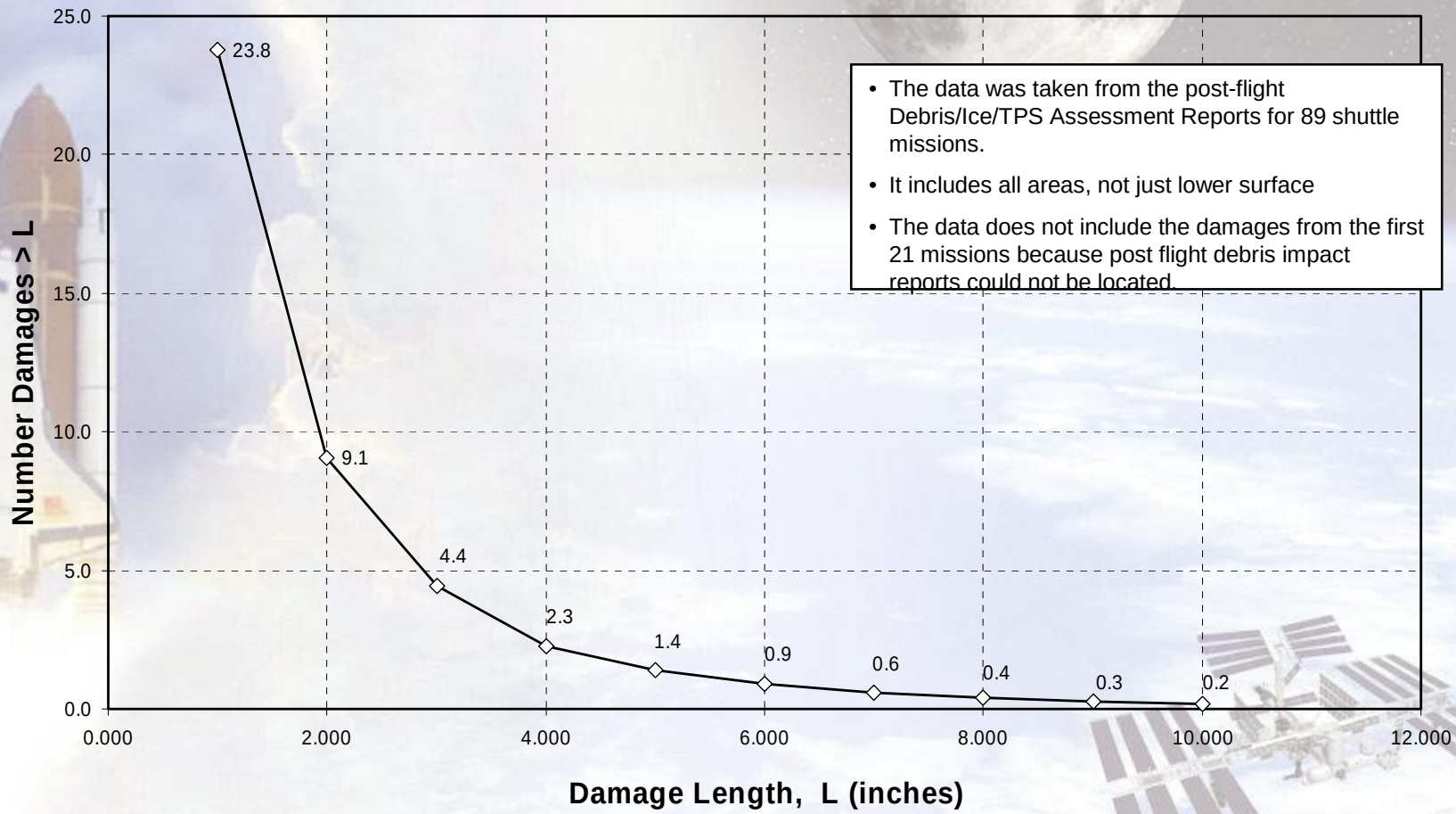
Mission		Impacts > 1“	Total Impacts
STS-9	6	14	58
STS-61C	7	39	193
STS-28R	8	20	76
STS-32R	9	15	120
STS-35	10	17	147
STS-40	11	25	197
STS-50	12	45	184
STS-52	13	16	290
STS-55	14	13	143
STS-58	15	26	155
STS-61	16	16	97
STS-65	17	21	151
STS-73	18	26	147
STS-75	19	17	96
STS-78	20	12	85
STS-80	21	8	93
STS-83	22	13	81
STS-94	23	12	90
STS-87	24	132	308
STS-90	25	20	131
STS-93	26	49	208
STS-109	27	18	98
OV-102 Average		26.1	143.1
Fleet Average		30.5	144.9



STS-109 Lower Surface Impact Damage

Flight Damage History

Average Number of Impact Damages Exceeding Length L per Flight



Historical Tile Damage Background

- Orbiter has sustained greater than ~15,000 tile damage events (of varying degree) throughout life of Program
- Per knowledgeable TPS technical community, only "a few" damage sites would have been candidates for even considering an on-orbit repair, had that option been available, based on ground inspection post-flight
- Our flight history tells us that tile gets damaged during ascent on every flight
  - Judgment would also say that the modifications to the other elements will not preclude our tile damage "flight history" from being generally repeated on future flights (although some possible improvement against "big" damages is predicted)
- Our flight history tells us that the vehicle is robust to enter with the tile damage suffered to date for the particular mission conditions experienced
- Two potential "really tough" scenarios brewing:
  - Pre-flight risk: TRP, solely using TRP delivered use-as-is analytical tools, is only able to validate a very small inspection criteria and, based on our flight history, drive a recommendation toward a very ops intensive / timeline impacting OBSS inspection process per flight. (an inspection criteria that just doesn't "feel right" based on our gut)
  - Real-time risk: Real-time team, solely using TRP delivered use-as-is analytical tools, recommends performing high-risk repairs at a high rate of frequency (a rate that just doesn't "feel right" based on our gut)… but has nothing else to provide any technical rationale to stand behind.

Pre-Flight Risk Assessment Philosophical Approach

Raw Data Activity, Creating the RAIV data set

Data Mining/Formatting
"Retro-actively" apply the tile damage inspection criteria
(3" for acreage, 1" around door seals)
to previous flight history capturing violations per flight and per PRACA zone

Note: No available information for STS-41B & STS-41D, STS-1 through STS-5 eliminated from data set due to old and significantly different configs we were not interested in capturing, other major excursion flights (STS-27R, STS-87) to be discussed in more detail later.

Technical Judgment

TPS PRT Review
Review all inspection criteria violations and provide a judgment as to which of the violations should be considered "close calls"

TPS PRT Review
Review "close calls" and provide a judgment as to whether "close calls" should be filtered out of data (i.e., not ascent debris, confidently corrected and verified debris source, etc.)

TPS PRT Review
Review "close calls" and provide a judgment as to whether any other "forward looking" augmentation factors should be applied

Result: "Residual Risk"

Any "Big Damage" trends seen along the way?

Statistical Activity

Statistical "Crunching"
Using flight history data and "residual risk", perform assessment to determine:
1) Likelihood of OBSS inspection requirement
2) Likelihood of "close call" damage

Pre-Flight Risk Assessment
Observations, Results, & Conclusions

	Region	CASE1 Total Hits	CASE1 Percent of Total	CASE1 Laplace Score	CASE1 Mean	CASE1 95th	CASE2 Total Hits	CASE2 Percent of Total	CASE2 Laplace Score	CASE2 Mean	CASE2 95th	CASE3 Total Hits	CASE3 Percent of Total	CASE3 Laplace Score	CASE3 Mean	CASE3 95th
Class Totals	Vehicle Total	549	100.0%	-8.5	5.3	17.4	175	100.0%	-2.1	3.5	8.6	150	100.0%	-2.4	3.0	7.1
	Lower Surface Tile Total	431	78.5%	-7.5	4.2	16.4	137	78.3%	-1.8	2.7	7.6	121	80.7%	-2.0	2.4	6.0
	Generic Acreage Subtotal	189	34.4%	-4.3	1.8	6.9	70	40.0%	-0.1	1.4	4.0	66	44.0%	-0.2	1.3	4.0
	Wing Glove Subtotal	60	10.9%	-2.8	0.6	1.0	25	14.3%	1.3	0.5	1.0	12	8.0%	1.8	0.2	1.0
	Aero Surfaces Subtotal	37	6.7%	-0.1	0.4	1.0	16	9.1%	0.0	0.3	1.0	17	11.3%	-0.3	0.3	1.0
	Special Penetration Areas Subtotal	145	26.4%	-6.2	1.4	5.9	26	14.9%	-5.3	0.5	3.0	26	17.3%	-5.0	0.5	3.0
	No Zone ID Subtotal	47	8.6%	-7.1	0.5	2.0	0	0.0%	Sparse	Sparse	Sparse	0	0.0%	Sparse	Sparse	Sparse
	Upper Surface Tile Total	71	12.9%	0.8	0.7	3.0	38	21.7%	-1.0	0.8	2.6	29	19.3%	-1.4	0.6	2.0
	Wing Glove Right	35	6.4%	-4.2	0.3	1.0	10	5.7%	0.0	0.2	1.0	5	3.3%	0.0	0.1	1.0
	Wing Glove Left	25	4.6%	0.6	0.2	1.0	15	8.6%	1.7	0.3	1.0	7	4.7%	2.4	0.1	1.0
	Generic Acreage Right	70	12.8%	-1.4	0.7	3.0	28	16.0%	-0.9	0.6	2.6	27	18.0%	-0.7	0.5	2.6
	Generic Acreage Left	86	15.7%	-5.0	0.8	4.9	25	14.3%	1.8	0.5	2.6	22	14.7%	1.9	0.4	2.0
	Wing and Acreage Right	105	19.1%	-3.6	1.0	3.0	38	21.7%	-0.7	0.8	3.0	32	21.3%	-0.6	0.6	2.6
	Wing and Acreage Left	111	20.2%	-4.1	1.1	6.0	40	22.9%	2.5	0.8	2.6	29	19.3%	2.8	0.6	2.0

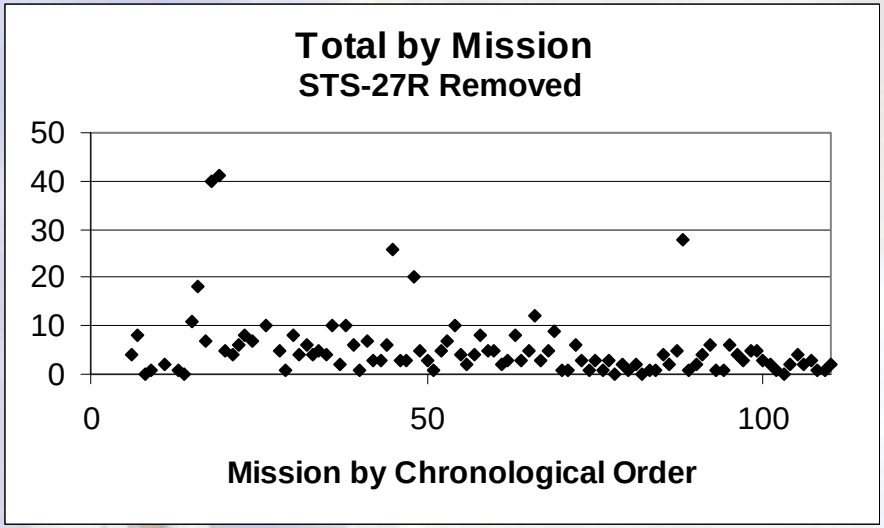
OBJ2

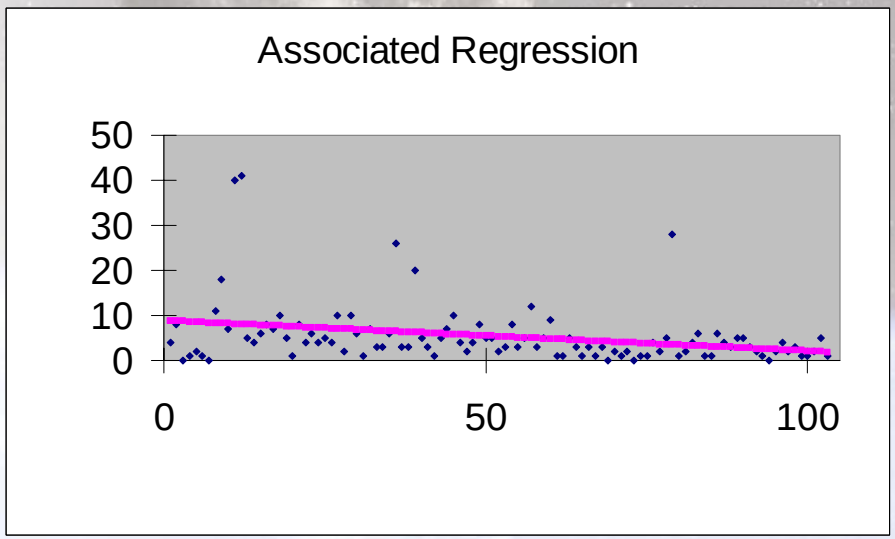
Legend	
CASE1 =	Total RAIV data set (103 missions), excluding STS-1 thru STS-5 and STS-27R
CASE2 =	RAIV data set for the last 50 missions only
CASE3 =	RAIV data set for the last 50 missions only, excluding STS-87

*** Green denotes a decreasing trend, red denotes an increasing trend**

George K. Gafka 281-483-7732

Pre-Flight Risk Assessment: Observations, Results, & Conclusions

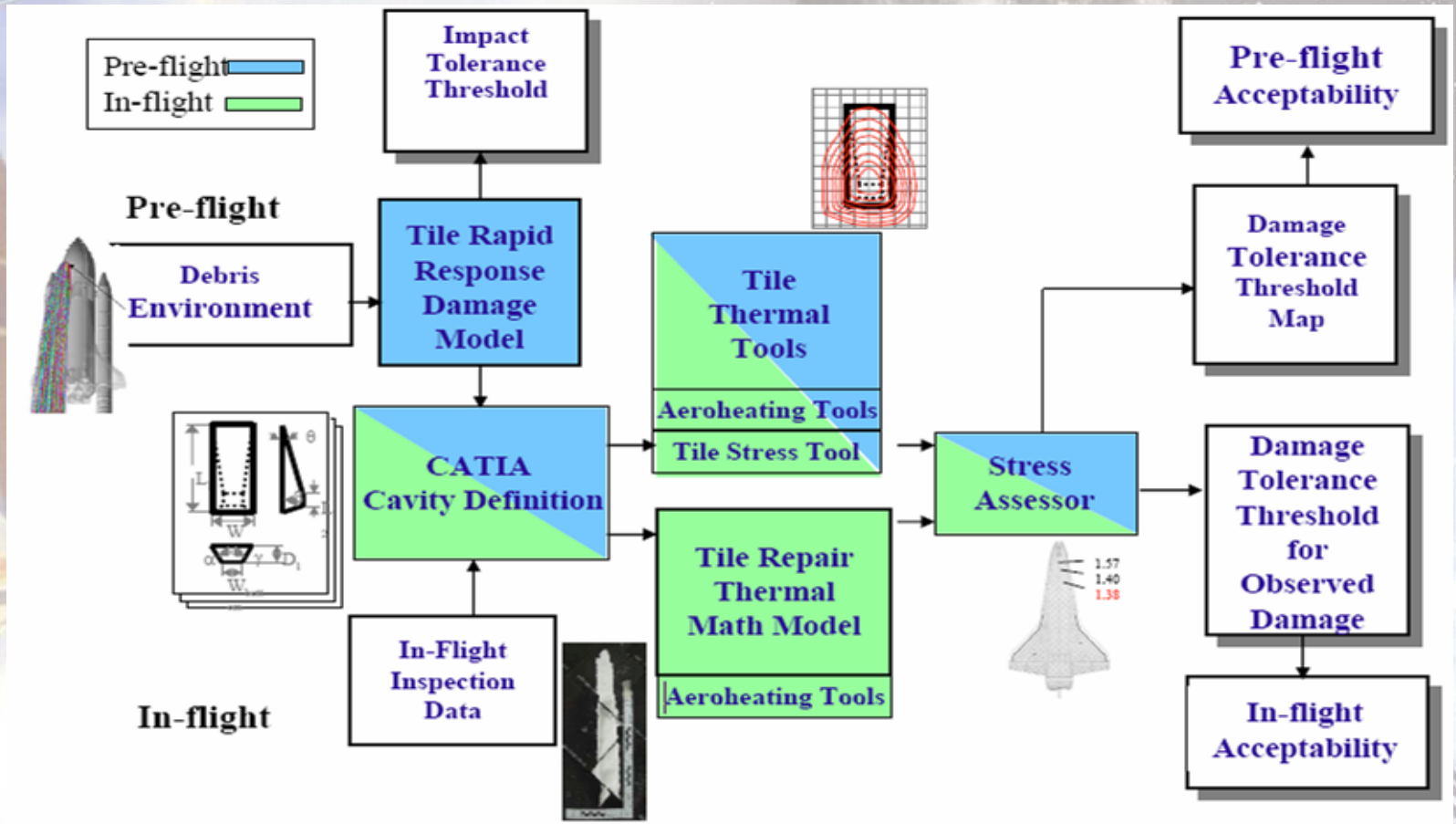




These graphs portray the total significant hits by mission ordered chronologically, less STS 1- 5 and 27R. Evident from both graphs is the general downward trend in total number of significant hits with a greater degree of variability in the first 50 as compared with the last 50. This is indicative of a distribution that, over time, has a decreasing mean and variance. This is similar to a production process that has increasing control and a lowering set point.

Legend	
CASE1 =	Total RAIV data set (103 missions), excluding STS-1 thru STS-5 and STS-27R
CASE2 =	RAIV data set for the last 50 missions only
CASE3 =	RAIV data set for the last 50 missions only, excluding STS-87

Tile Models to Determine Impact and Damage Tolerance Thresholds



RCC and Tile Tools and Models

Models	New / Updated / Existing	Used For Pre-Flight C/E	USED REAL TIME			
			Launch Go/No-Go	On-Orbit before Inspection	On-Orbit Use-as-Is	On-Orbit Repair
RCC Damage Prediction Tools						
LESS Dyna Tool	N	X		X		
Rapid Response RCC Damage Prediction Tool	N		X	X		
RCC Aeroheating Tools						
Step/Ramp Heating	N					X
LESS Breech Internal Flow Model	N				X	
RCC Damage Growth Tool	N				X	
RCC Thermal Models						
RCC 3D Thermal Math Models	E				X	X
Tile Damage Prediction Tools						
Tile Rapid Response Damage Model (foam)	N	X	X	X		
Tile Rapid Response Damage Model (ice)	N	X	X	X		
Tile Screening Tool	N	X				
Tile Aeroheating Tools						
Cavity Heating Database	N	X			X	
CFD for Cavity Heating	N	X			X	
Catalytic Heating Tool	N	X			X	
Boundary Layer Transition Prediction Tool	N	X			X	X
Tile Thermal Tools						
2D Thermal Model	N				X	
3D Acreage Tile Thermal Model	N	X			X	X
Repaired Tile Thermal Model	N					X
Special Configuration Thermal Models	N				X	
Tile Stress Tools						
Tile Stress Tool	N	X			X	X
Tile Bondline Integrity Tool	U	X			X	X
Stress Assessor Tool	N	X			X	X

ORB-230

Observations, Ideas, and Opinions
Presentation Outline

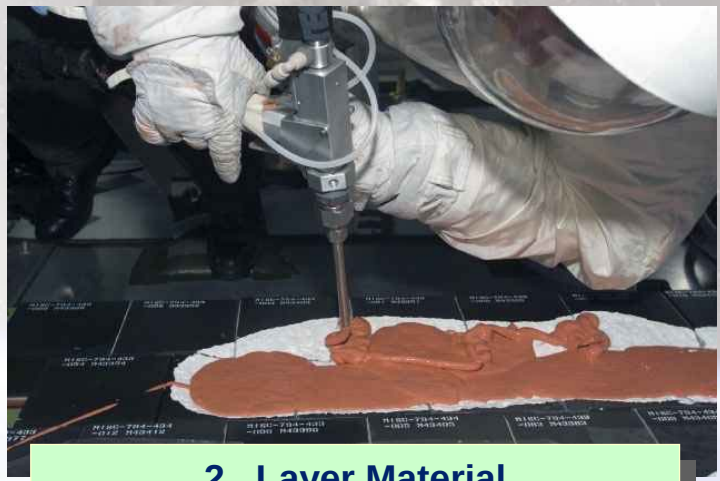
- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

You are here.

- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

Repair Procedure Overview

1. Trim Gap Filler as Required
   Clean Tile with Gel Brushes

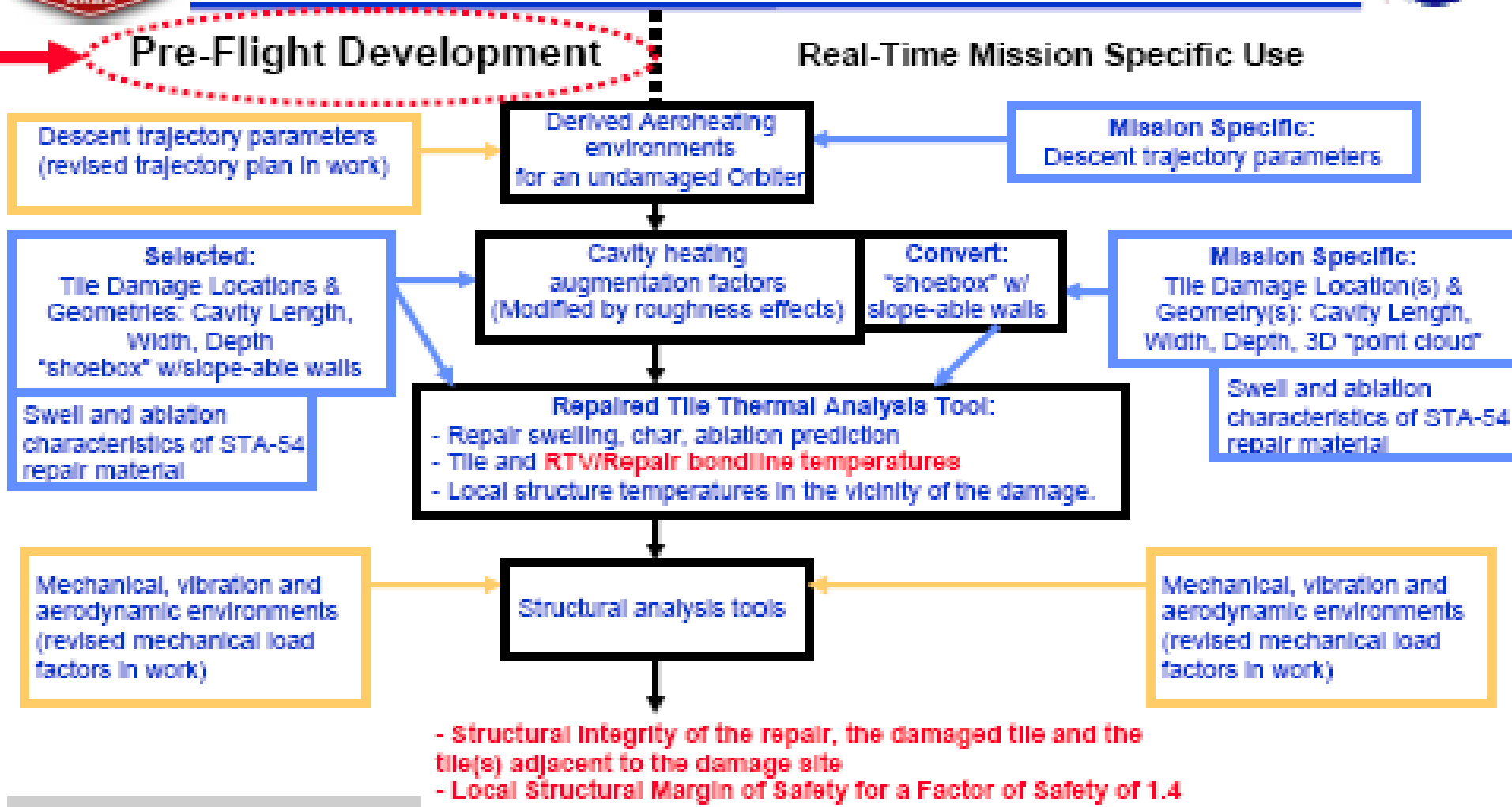


2. Layer Material

3. Flatten / Smooth Repair

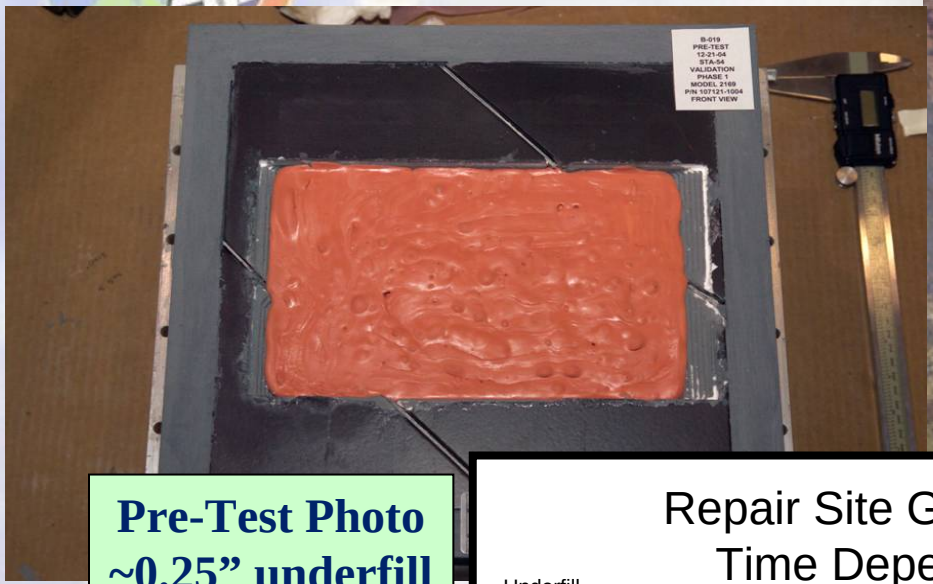
George K. Gafka 281-483-7732

Development of TRP Repair Disposition Analytical Tools

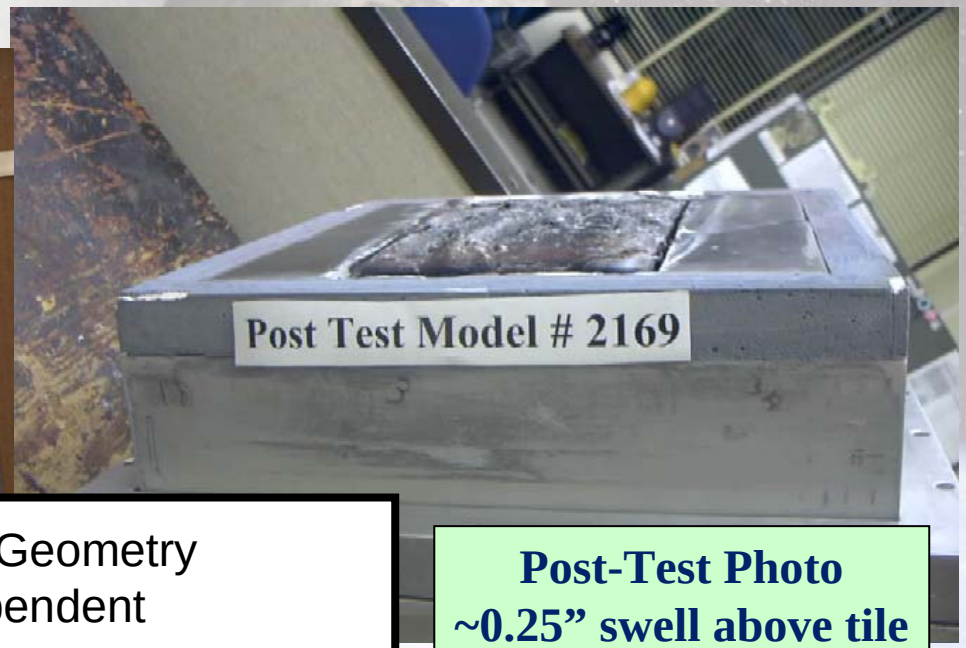


George Gafka
281-483-7732

Test Article Exposed to Low Shear Test Condition Model #2169 – 9”x5” Cavity Filled in HTV 2

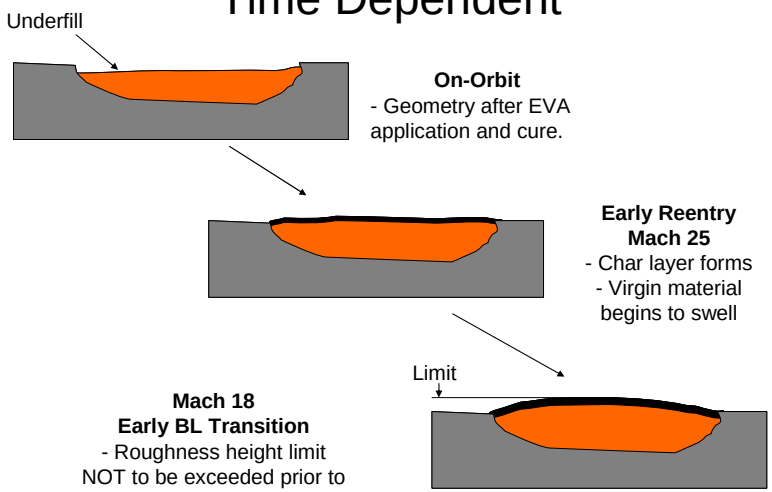


Pre-Test Photo ~0.25” underfill



Post-Test Photo ~0.25” swell above tile

Repair Site Geometry Time Dependent

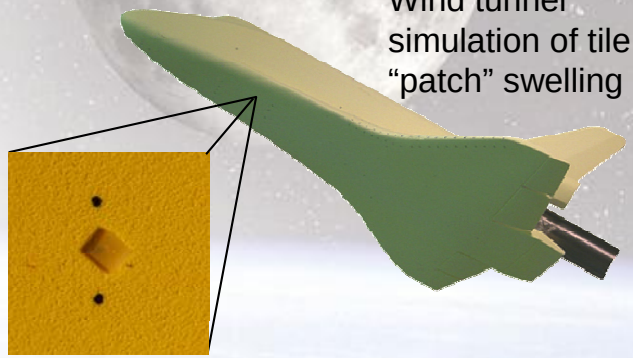


George K. Gafka 281-483-7732

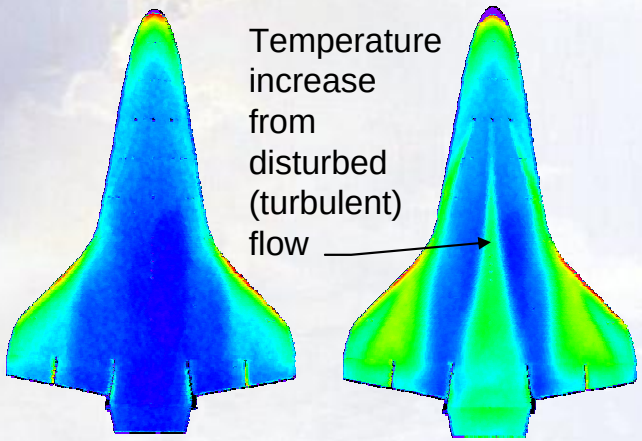
Development of Transition Prediction Methodology

Tile repair

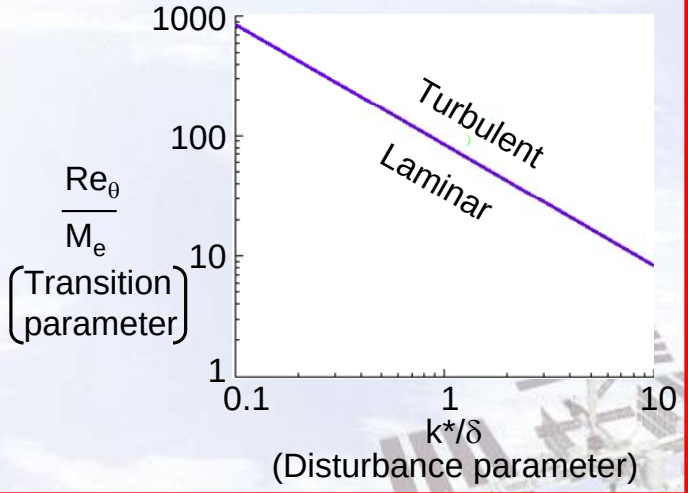
Insulating char layer (ablating/swelling)



Wind tunnel simulation of tile "patch" swelling

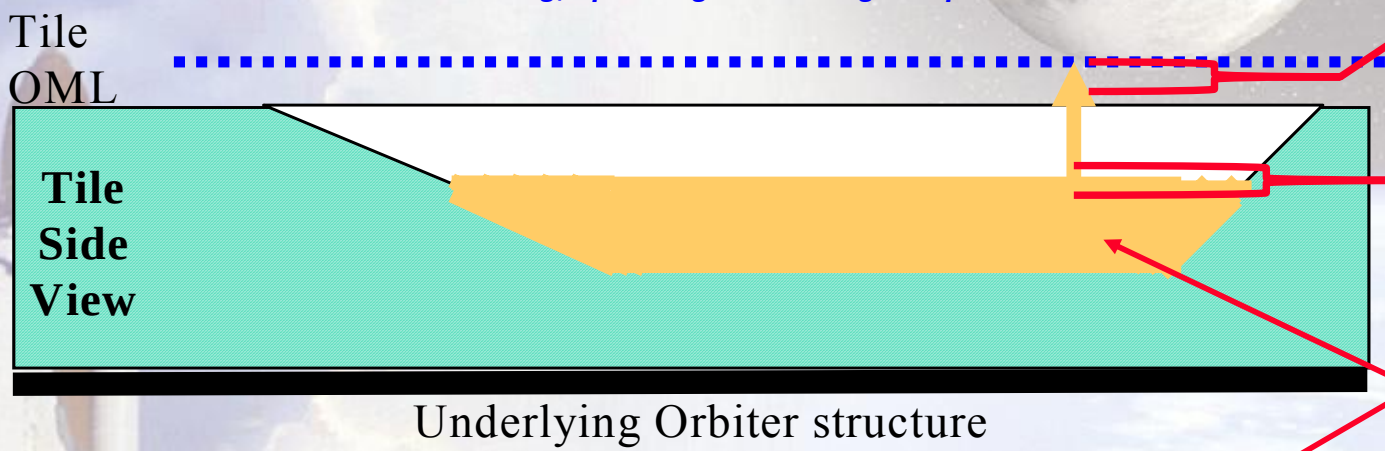


Temperature increase from disturbed (turbulent) flow



LOCAL DAMAGE SITE
Trade-space result unknown at this time!
RESULT: Possible Capability Black-Out Zones

CONSTRAINT: Protect allowable OML protuberance requirement
Relief via scrubbing, operating outside flight experience



Material swell and swell variability part of rack-and-stack tolerance assessment for meeting OML
Performance Today?

EVA tool and technique accuracy part of rack-and-stack tolerance assessment for meeting OML
Performance Today?

Thermal performance of repair material provides underfill capability while protecting structure
Performance Today?

CONSTRAINT: Protect back-plate temperature (positive structural margins for entry)
Relief via scrubbing, FOS reduction, etc.

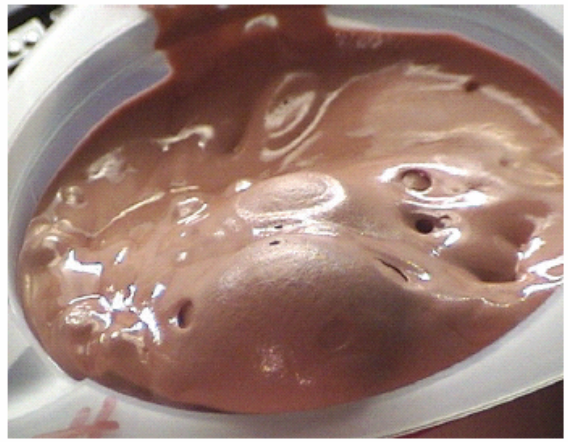
Note: There is also a "global" or downstream effect that must be considered. This can result in additional blackout zones if "low margin" healthy or damaged downstream tiles see elevated temperatures that would result in the underlying structure temperature exceeding allowable limits.
Relief via scrubbing, FOS reduction, etc.

Killer/"Golden" Requirements
Thou shall have NO bubbles…

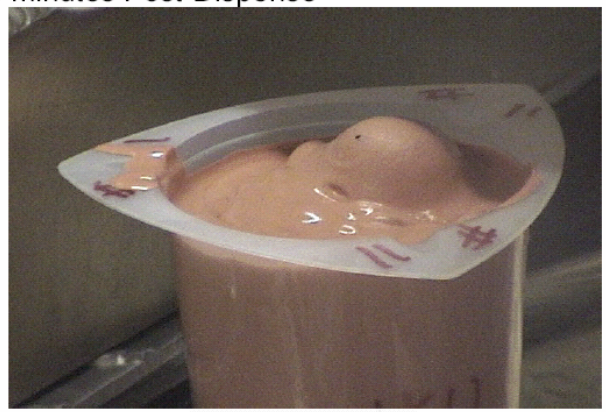
- Initial sample, Part A - CIPAA 1005

Following Dispense

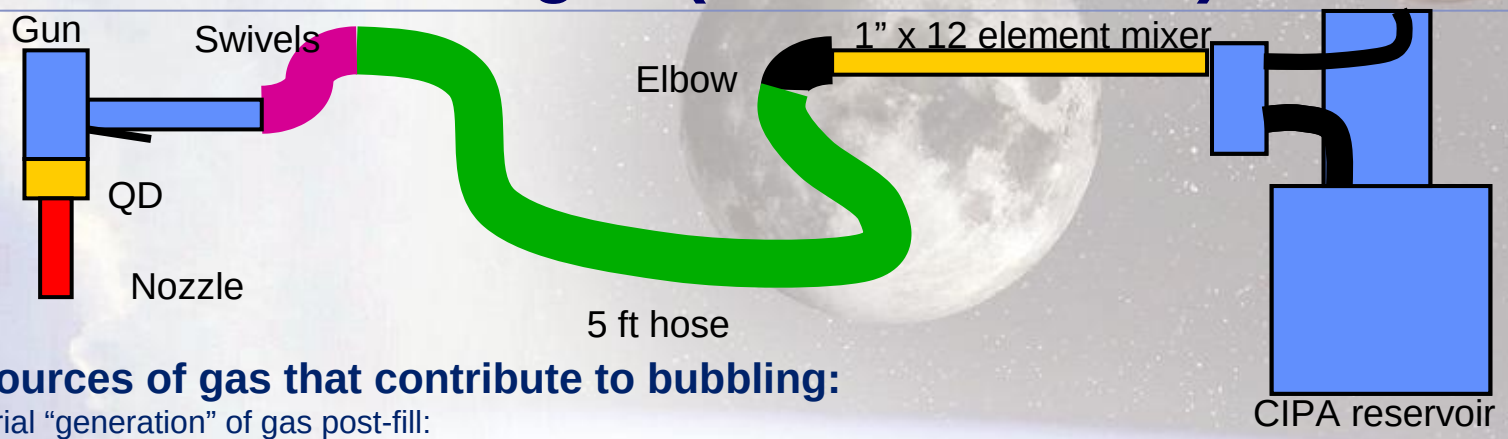
15 minutes Post-Dispense



- Initial sample, Part A - CIPAA 1005
- 30 minutes Post-Dispense



Example of Hardware/Test Configuration Sources of gas (5 sources?!?!)

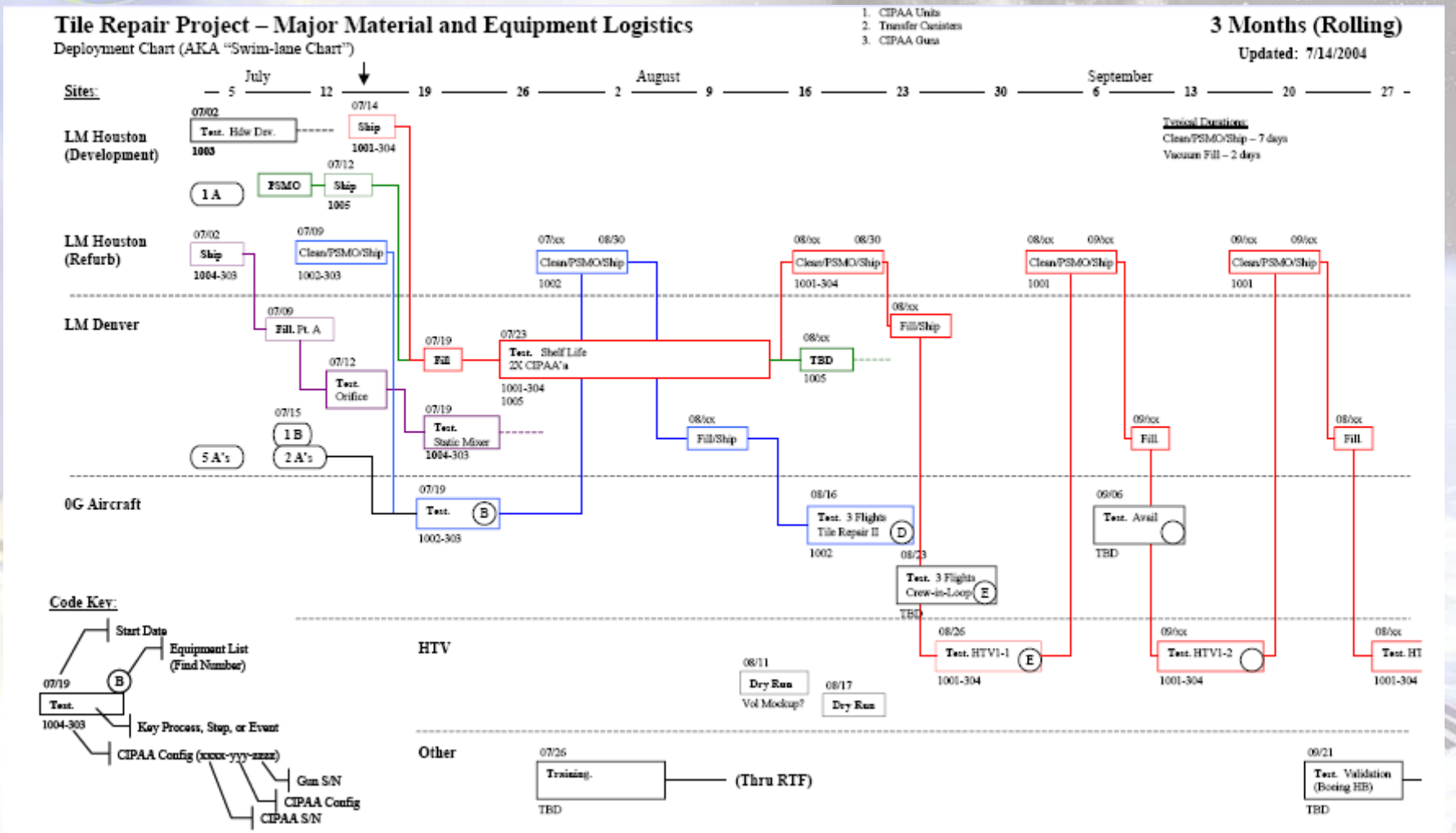


Five possible sources of gas that contribute to bubbling:

- Internal-to-the-material “generation” of gas post-fill:
  - **1** Residual gas remaining in material (Part A) post degassing
    - Resulting gas could nucleate into bubbles over time, could be “pulled out” of solution with pressure drop (cavitation)
    - ***Data suggests likely contributor, can’t fully exonerate or confirm***
  - **2** Micro-balloons breaking post degassing
    - Resulting gas could nucleate into bubbles over time, could be “pulled out” of solution with pressure drop (cavitation)
    - ***Analysis suggests extremely sensitive to number allowed to break, possible contributor, can’t fully exonerate or confirm***
  - **3** Ethanol???
- External-to-the-material influences “feeding” the material gas:
  - **4** Ambient air leaking past environmental seal during storage
    - Could nucleate into bubbles over time, could be “pulled out” of solution with pressure drop (cavitation)
    - ***Data suggests likely contributor, can’t fully exonerate or confirm***
  - **5** Nitrogen pad pressure leaking past dynamic seal during system pressurization
    - Could nucleate into bubbles over time, could be “pulled out” of solution with pressure drop (cavitation)
    - ***Data suggests NOT a likely contributor, can’t fully exonerate or confirm***

Conclusion: No way to fully preclude bubbling with this material/hardware system! So, instead how sensitive is system/entry performance to bubbles?

Logistics Deployment Chart
Near Term Planning Tool



Tile Repair – STA-54 Material / Hardware Process Improvements and Test Timeline

Bubbles Appear
KC135 Gun (Experimental)
June 2004

ROSS 12 Gal. Vacuum Mixer
July 2004

Small Cone Degas
Sept. 2004

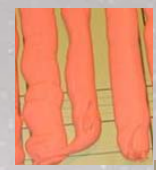
Modified Flight Gun
- Swivel
- Dual Hose

Oct. 2004

12 Gallon Degas
November 2004

Current Improved Material
12/6/04

STA-54 on +70 deg F Surface



STA-54 on -70 deg F Surface

HTV Run 2
12/15/04

Fully Dense Material

Cure as expected

JAN. 2005

Aug. 2004
Flight Prototype Gun
- Variable Flow Rate
- Small orifice

June 2004
Fault Tree Analysis

Sept. 2004
Flight Prototype Gun
- Single Flow Rate

Sept. 2004
Modified Flight Gun
- Swivel
- Positive Flow Shut-off
- Single Hose

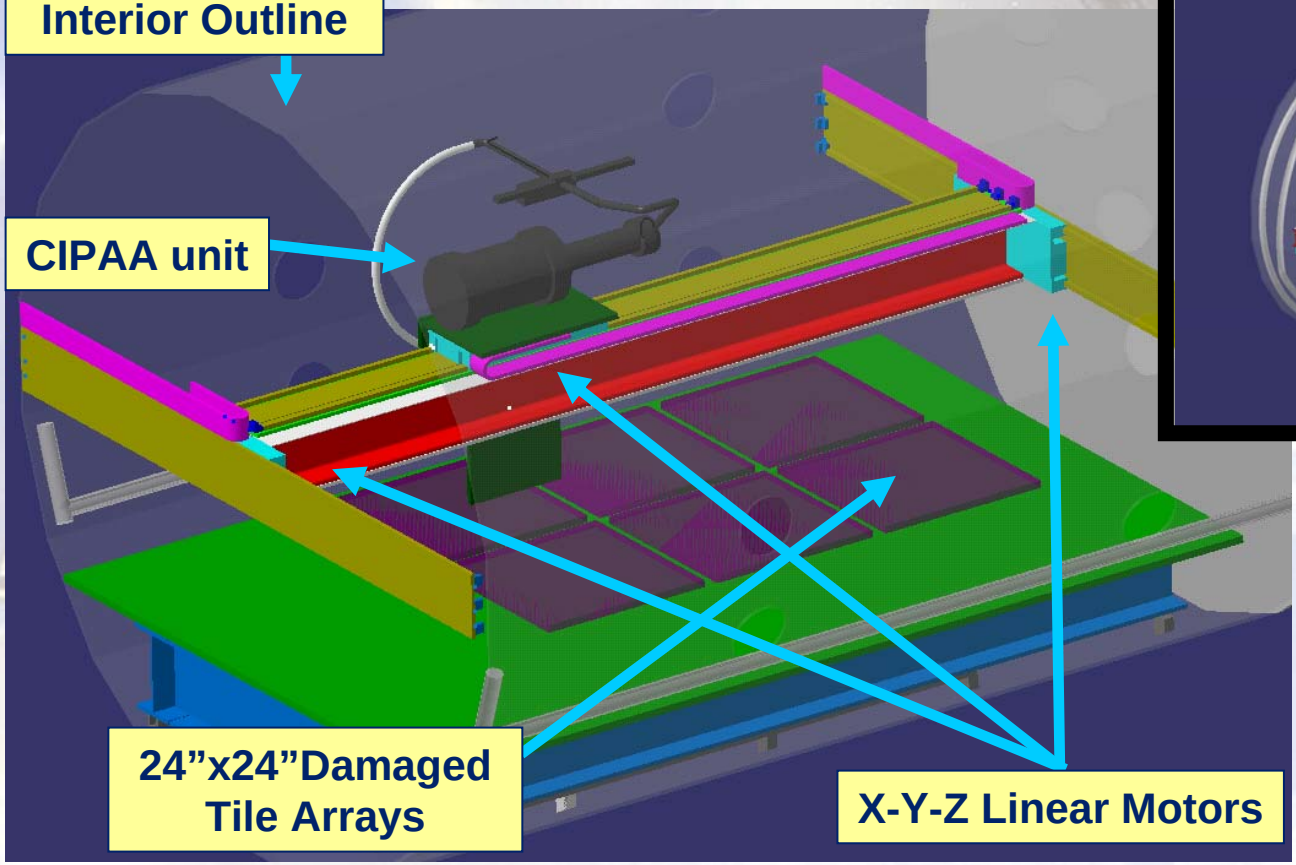
November 2004

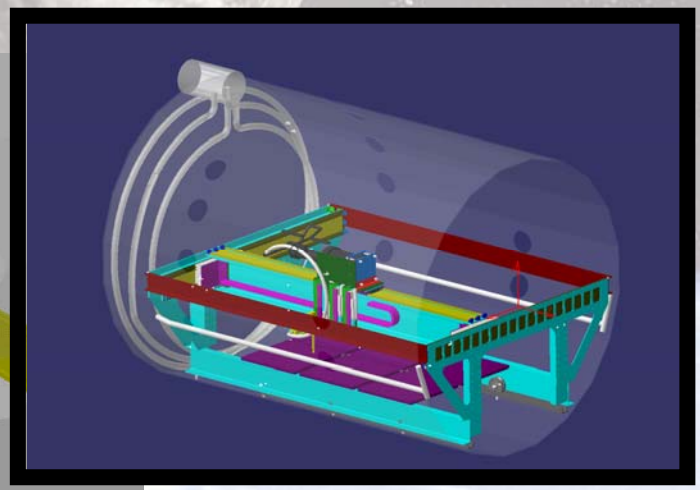
CIPAA 1002 11/19/04
Gel Cup #2 @ 300 psi

Arc Jet

HTV Run 1
12/8/04

Repair Ground Test Equipment Gantry System Configuration





STA-54 VOID EFFECTS TEST PROGRAM

MODEL #2216 PRE AND POST TEST PHOTOS
0.25 INCH UNDERFILL
COMPRISED OF THREE 0.50 INCH THICK LAYERS

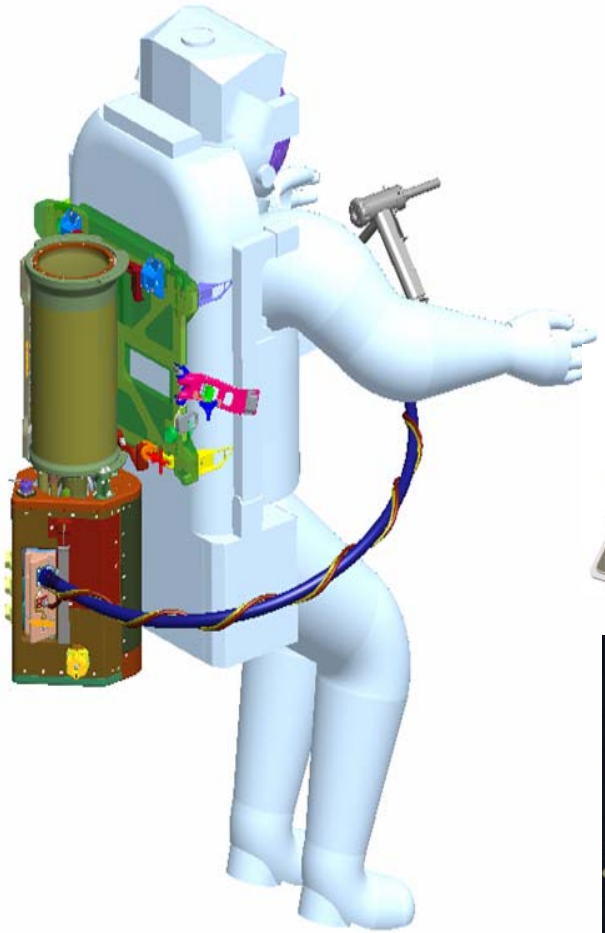
Observations, Ideas, and Opinions
Presentation Outline

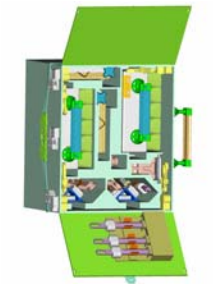
- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

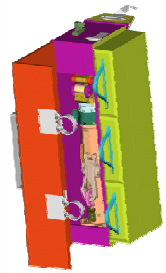
You are here.

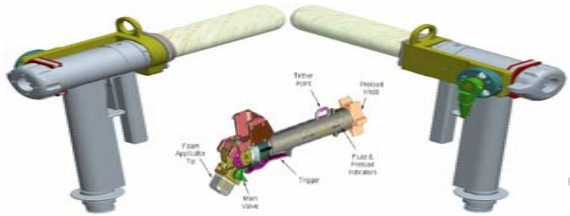
- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

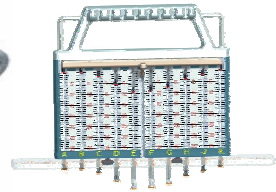
Tile Repair Hardware Suite

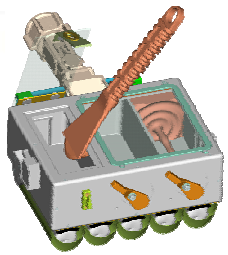


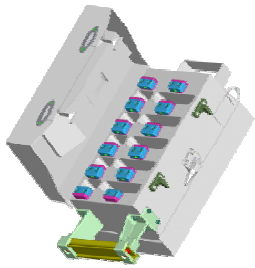


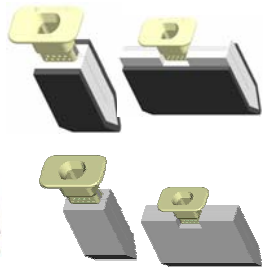




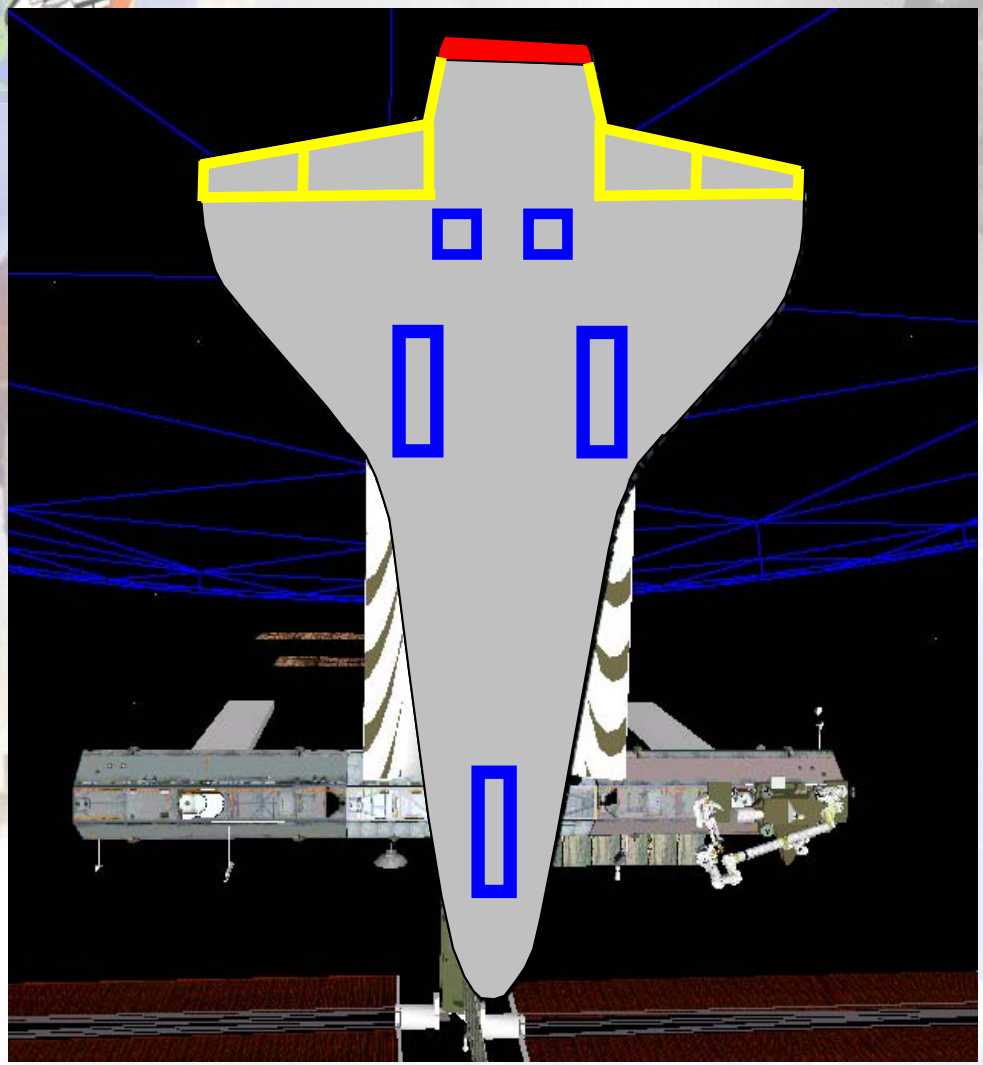








Tile Repair Project – A View of Project Scope



RTF

- Door Seals
- Acreage

Future

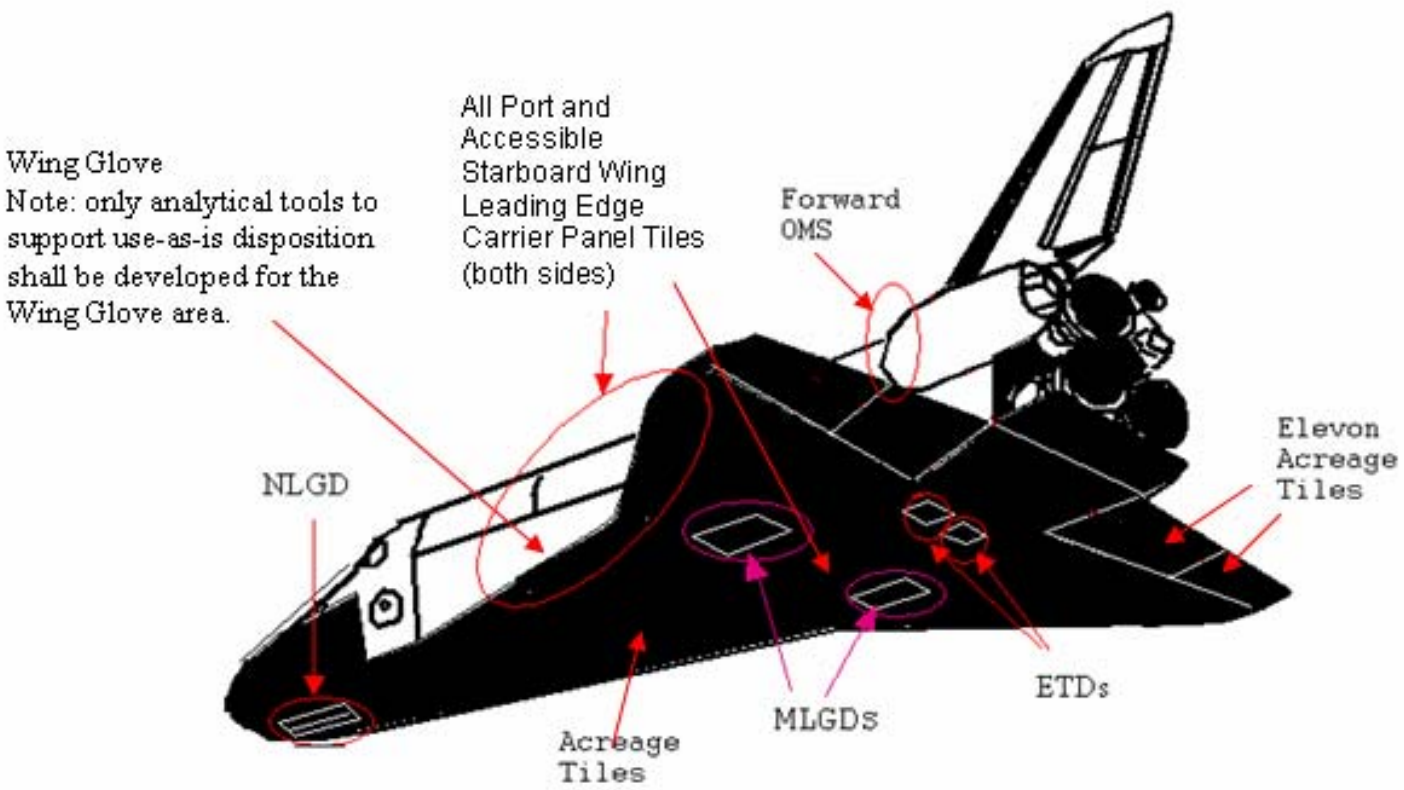
- No Access
- Challenging Geometry

Tile Repair Project – A View of Project Scope

TPS Area	Likelihood of Damage	Conseq. of Damage *TBR	Detect-ability	Current EVA Access-ability	Current Design Appr Compatible w/damage?	RTF Support-ability	Required for RTF (TRP opinion)
Acreage Tile (Lower Surface)	?	H > 3”	Yes	Yes	Yes	H	Yes
Chine/Wing Glove	?	H > 3”	Yes	Yes	At risk	L	Yes/No?
Door Seals	?	H > 1”	Yes	Yes	At risk	M	Yes
LESS Carrier Panels	?	H > 1”	Yes	1 – 20, Yes	At risk	M	Yes
				Outboard, No	At risk	L	No
Elevon	?	H > 3”	Acreage Only	Acreage, Yes	Yes	Acreage, H	Yes
		H > 1”		Other, No	Hinge, At Risk	Hinge, L	No
Vertical Tail	?	H > 3”	No	No	At risk	L	No
OMS Pod Tile	?	H > 3”	Not Inspected	Forward edge only	Accessible Acreage only	Acreage, H	Yes
				Other, No	Other, No	Other, L	No
Body Flap	?	H > 3”	Acreage Only	Forward acreage, Yes	Acreage, Yes	Acreage, H	Yes
				Other, No	Other, No	Other, L	No

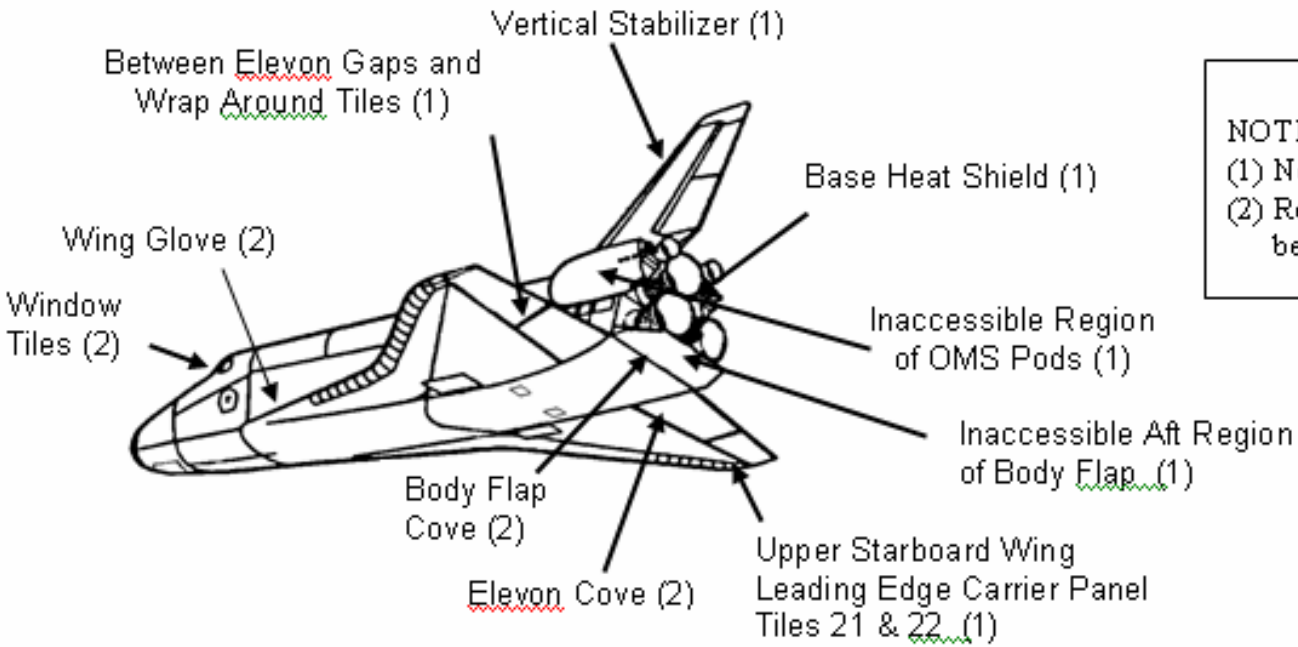
System Requirements for RTF

Figure 3.2-1 Tile Damage Assessment and Repair Locations



System Requirements for RTF

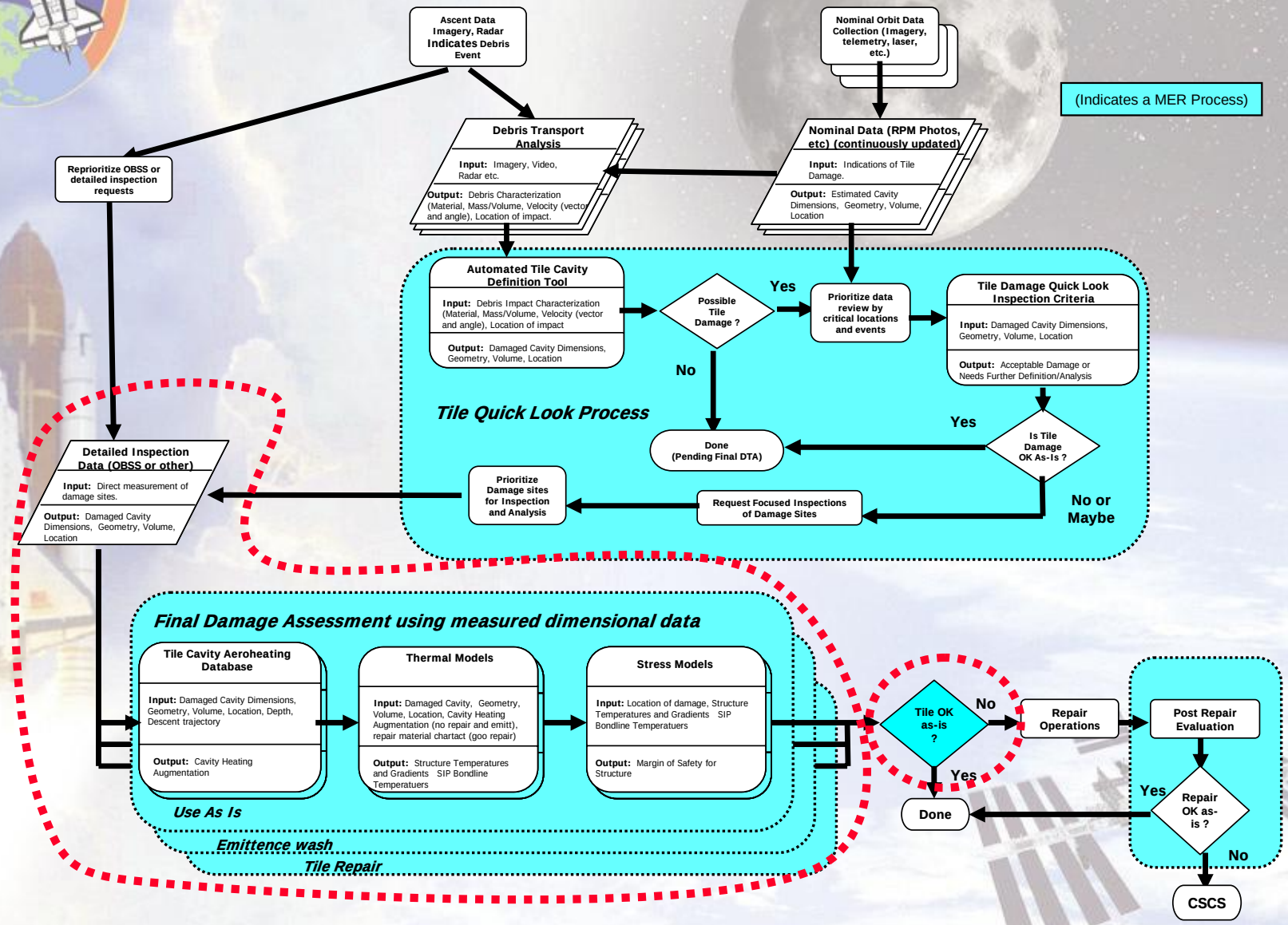
Figure 3.2-2 Examples of Tile Locations Not Explicitly Repairable by TRP



NOTES:
(1) No EVA Access
(2) Repair Configuration Cannot be Standardized or Analyzed

Real-Time

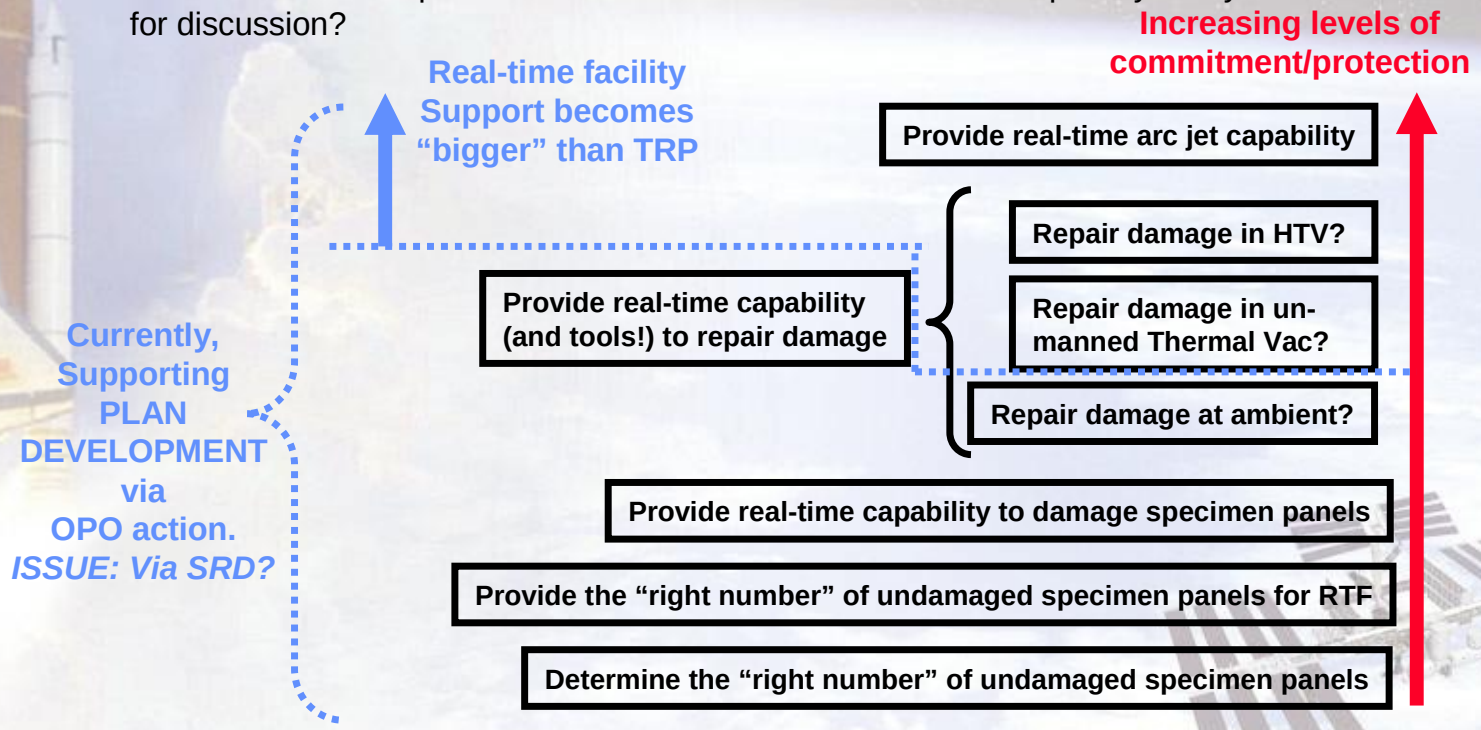
Tile Damage Assessment Process



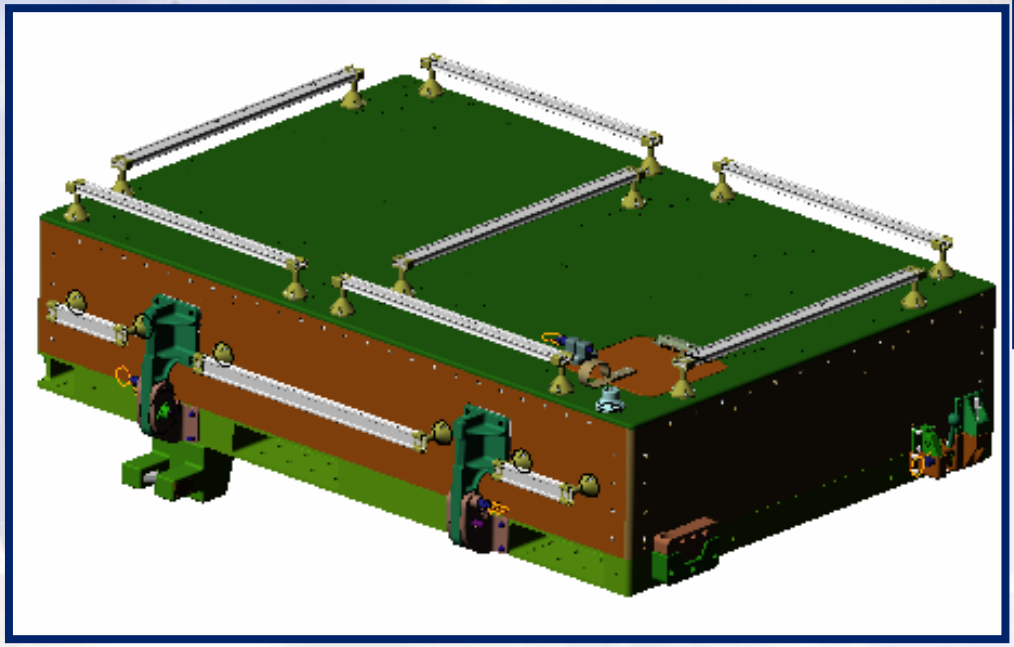
Real-time Ground Test Capability (HTV, arc jet, etc.) for mission-specific damage/repair

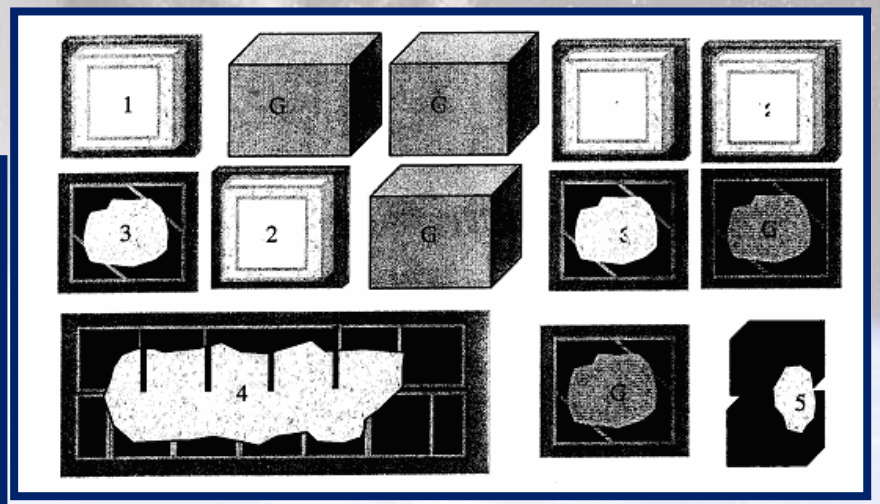
●OPO/Program Direction

- –Should TRP SRD contain requirements for providing deliverables and damage capability or continue to work to OPO action?
  - »Envisioned to be a part of nominal mission capability or short-term requirement for first few flights?
- –What is the forward plan to take the "Real-Time Ground Test Capability" story forward to the Program for discussion?



Thermal Protection System (TPS) Repair Development Test Objective (DTO)





Tile Repair Project Conclusion

- **Use-As-Is Analytical Tools**
  - **Rigorously developed, test anchored, peer reviewed, documented, "simmed" and "certified" in support of Return To Flight (STS-114)**
  - **Required and used successfully during STS-114 mission**

We had to, and we did!

- **Historical Database**
  - **Supplemental tool developed/delivered in support of Return To Flight (STS-114)**
  - **Used as a sanity check for use-as-is predictions pre-flight**
  - **Used successfully during STS-114 mission as a supplement to damage disposition activities**

We made happen!

- **Tile Repair Capability**
  - **Best effort delivered and flew on STS-114**
  - **Safe to fly, safe to use, system level functional performance for repair not certified, best data to date available for assessment**
  - **Further CIPAA ("goo-based") development recently canceled with continued support of other repair capabilities**

Best we could do!

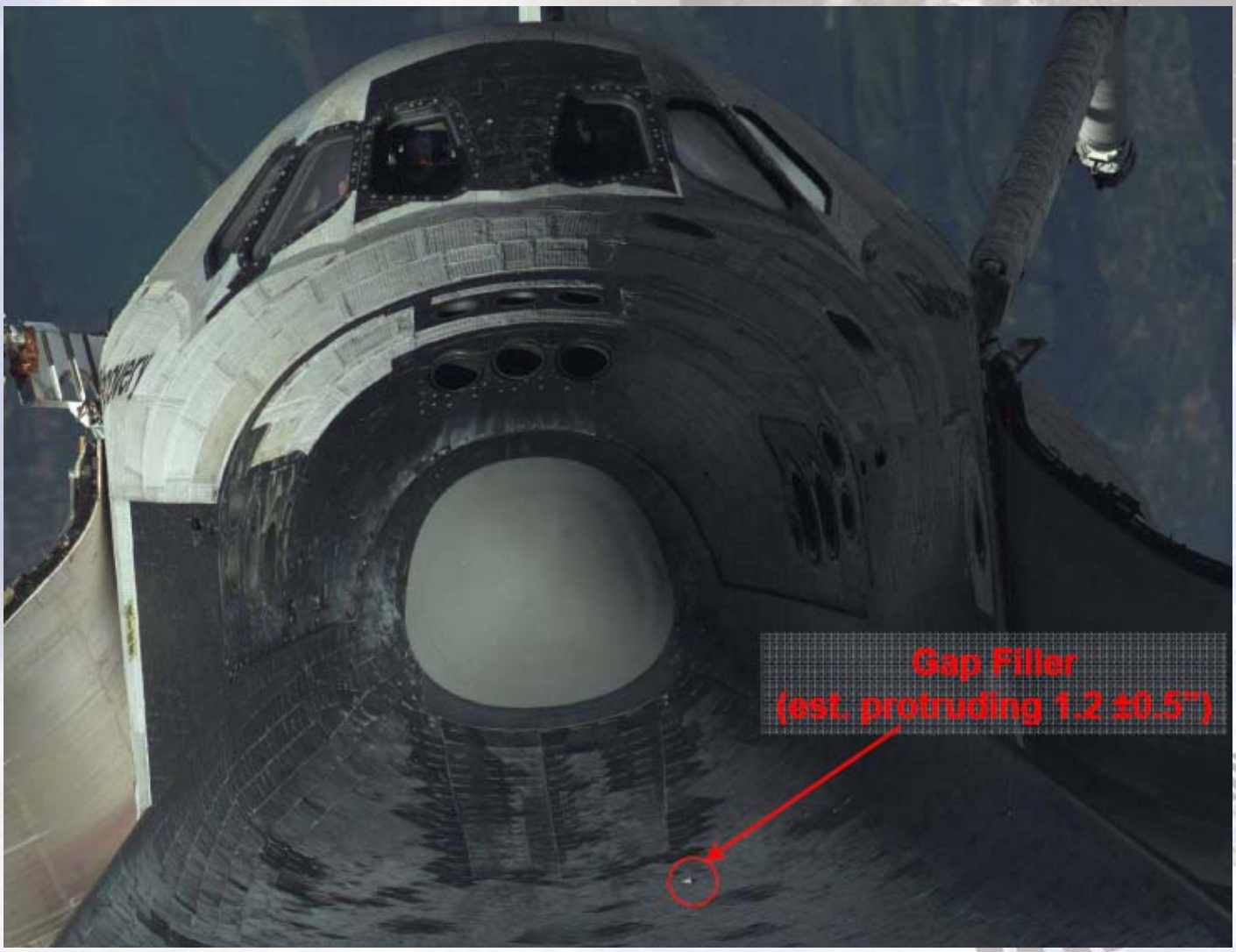
Observations, Ideas, and Opinions
Presentation Outline

- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

You are here.

- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

STS-114...
Flight Day 3, RPM "Quick Look"



Use-As-Is Risk Summary

KEY ASSUMPTION

1. BLT, Mach ~ 18

Current, "best estimate"

2. BLT, Mach 21.5

3. BLT, Mach 24

UNCERTAINTIES AND SAFETY RISKS

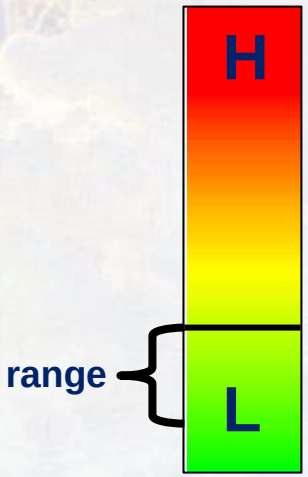
Aero Heating: trajectory, BLT Mach number and heat rate/heat load

Thermal/Structural Analysis for specified case

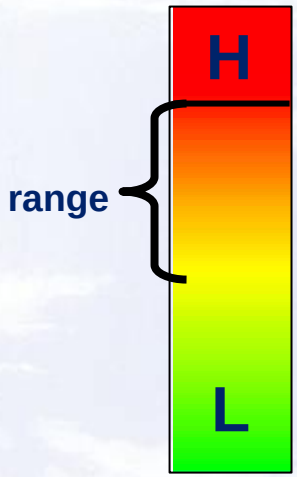
Flight History support of analysis

Flight Control Performance (Certified to Mach 19)

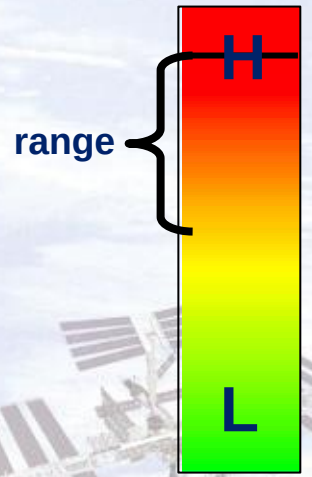
POTENTIAL CONSEQUENCES



Minor Vehicle Damage
Structural Integrity Maintained



Major Structural Damage / LOCV



Major Structural Damage / LOCV

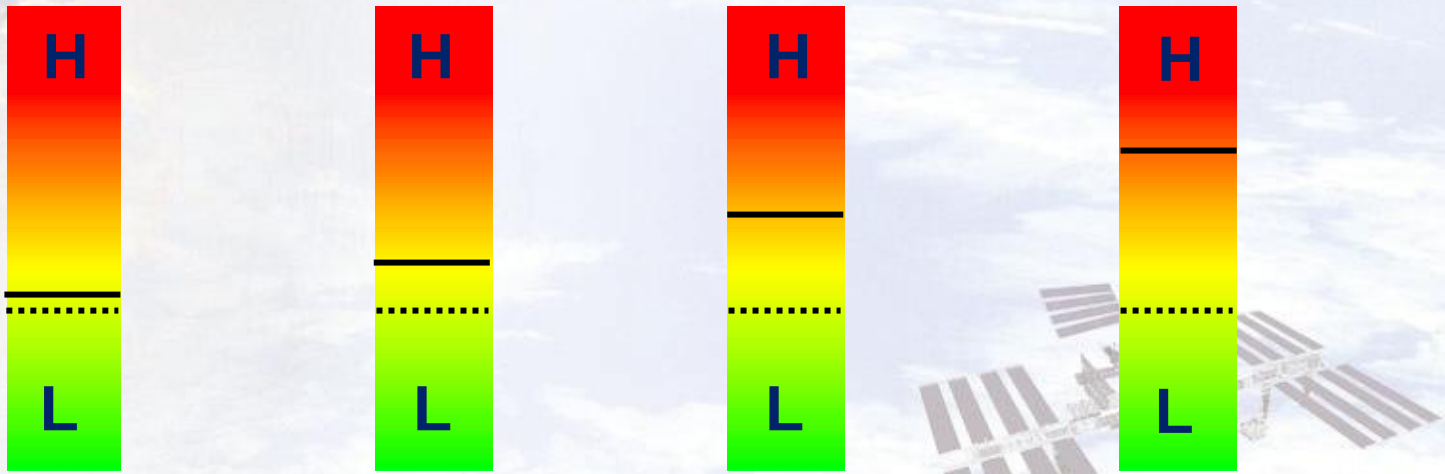
EVA Repair Risk Summary

EVA 3 - Shuttle Airlock - SSRMS

Expected outcome per KSC and TPS experts

REPAIR OPTION	1. Gap Filler Extraction - Finger	2. Gap Filler Extraction - Forceps	3. Hacksaw Cut	4. Scissors Cut
SAFETY RISKS: COMMON	Translation to/from Worksite and Inadvertent Damage			
SAFETY RISKS: UNIQUE (At the work-site)	Inadvertent Damage Repair Confidence	Inadvertent Damage Repair Confidence	Inadvertent Damage Repair Confidence Contamination/Dust/FOD	Inadvertent Damage Repair Confidence Contamination/Dust/FOD

COMMON



MISSION IMPACTS For a nominal EVA 3, all primary Mission objectives can be accomplished (no significant impact). Unexpected/ off-nominal EVA task durations may result in significant, recoverable, Mission impacts (additional EVA 4).

George K. Garka 281-483-7732

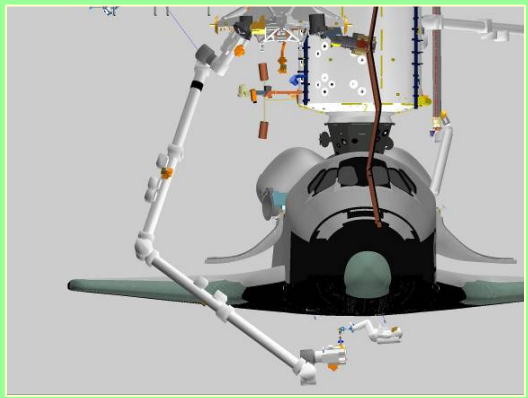
STS-114 MMT
Conclusions/Recommendations

Generic recommendation logic

- Recommend use-as-is disposition if, and only if:
  - Confidence exists that on-orbit configuration represents Case 1 (BLT, Mach 18)
  - NOTE: Likelihood appears low that we will get to here with confidence, especially in time frame that supports required MMT decision milestones
  - *NOTE: This risk is driven solely by high uncertainties in key areas!*

versus

- Recommend repair attempt/disposition if:
  - Confidence can not be established in the aero heating environments or vehicle response to those environments
  - Case 2 (BLT, Mach 21.5) or Case 3 (BLT, Mach 24) is likely scenario
  - Recommended repair order of implementation
    - Try first: Gap Filler extraction – Finger
    - Next: Gap Filler extraction – Forceps
    - Next: Hacksaw
    - Last resort: Scissors
    - *NOTE: Consistent with current EVA plan*
    - *NOTE: This risk is driven by consciously choosing to accept a, better understood and easier to control/manage (relative to use-as-is), risk*



Observations, Ideas, and Opinions
Presentation Outline

- Project Management & Systems Engineering Challenges
  - In The Beginning…What is your mission? Can you "certify" to it?
  - Team Roles/Responsibilities/Requirements/Contracts/Deliverables
  - Use-As-Is becomes most critical capability!
    - Flight History Database, a surprisingly contentious topic
  - Tile Repair is really tough, becomes "best effort" for RTF
    - Killer/"Golden" Requirements: Bubbles
    - Tough Trade Spaces
  - Delivery for RTF
- STS-114
- Conclusion

You are here.

- Understanding/Influencing/Accepting Your Environment
  - Cost, schedule, technical/safety, political, emotional
  - Evaluating/maximizing your influence potential
- Effective People Skills and Communication, a key to success!
  - Integrity/creditability
  - Teamwork/relationships/advocacy/negotiation
  - Up and out, (Presentation! Presentation! Presentation!)
  - Down and in, (reaching consensus where possible and recognizing where not)
  - Healthy tension, good push back

Typical "Peer Review" of Documentation

Required underfill dimension to account for swell at each location	TPS Mission Central Website	Flight Control Team	Damage Assessment Team	Prepare EVA Procedures
Analysis Report of damage sites.	TPS Mission Central Website	Damage Assessment Team	Analysis PRT	Used to prepare report specifying repair, or disposition
Presentation of dispositions	MER MMT	OPO	Damage Assessment	Used to turn on repair effort.

Deleted: Crew console TPS PRT¶ Real time

Deleted: Analysis PRT

Deleted: ¶

Deleted: TPS PRT

Deleted: OBO/ PIT/MMT

Deleted: TPS PRT

Formatted: Normal

Crew console

MER

- **Understanding/Influencing/Accepting Your Environment**
  - **Cost, schedule, technical/safety, political, emotional**
  - **Evaluating/maximizing your influence potential**
- **Effective People Skills and Communication, a key to success!**
  - **Integrity/creditability**
  - **Teamwork/relationships/advocacy/negotiation**
  - **Up and out, (Presentation! Presentation! Presentation!)**
  - **Down and in, (reaching consensus where possible and recognizing where not)**
  - **Healthy tension, good push back**

Presentation! Presentation! Presentation!

Typical day at the Space Shuttle Program Requirements Control Board (SSPRCB)

CR/ACTION OPR TITLE/ACTION DESCRIPTION

==========

S042013EV DELETE NITROGEN TANK AND AFT BALLAST BOX FROM JSC-MO STS 121, STS 300 AND STS 115 DEFER - 10/29/04 SSP PRCB PRESENTER(S): JSC-MO3----------

S050411AF SUBMITTAL OF DCN 041 TO HAZARD REPORT S.10, JSC-MX PARTIALLY OPEN GO2/GH2 VENT/ RELIEF VALVE INDICATED CLOSED DEFER - 10/29/04 SSP PRCB PRESENTER(S): MSFC-ET----------

S050430BG CHANGE TO BASELINE ORBITER HAZARD REPORT - JSC-MX ORBI 036 DEFER - 11/04/04 SSP PRCB PRESENTER(S): USH-0E ----

S050430BH CHANGE TO BASELINE ORBITER HAZARD REPORT - JSC-MX ORBI 256 DEFER - 11/04/04 SSP PRCB PRESENTER(S): USH-OE --

S060348 BASELINE SAFETY AND RELIABILITY REQUIREMENTS JSC-MO FOR SPACE SHUTTLE CARGO INTEGRATION HARDWARE DEFER - 10/29/04 SSP PRCB PRESENTER(S): JSC-MO2 ----------

S062190A PROVISION FOR REPLACEMENT SPECIFICATIONS IN JSC-EA SHUTTLE PROGRAM M&P REQUIREMENTS DEFER - 10/29/04 SSP PRCB PRESENTER(S): JSC-ES4 ----------

S062253 UPDATE TO SE-S-0073 SPECIFICATIONS FOR KSC-MK-SIO POTABLE WATER DEFER - 10/29/04 SSP PRCB PRESENTER(S): JSC-SF23 ----------

S062292A UPDATES TO APPENDIX R, THE SPACE SHUTTLE KSC-MK PROGRAM CONTINGENCY ACTION PLAN DEFER - 10/29/04 SSP PRCB PRESENTER(S): KSC-MK-SIO ----------

S062313 RETURN TO NIGHT LAUNCH OPPORTUNITIES JSC-MS JSC-MS/1-1 DEVELOP A PLAN TO DOCUMENT CRITERIA FOR RETURN TO NIGHT LAUNCH, INCLUDING OBJECTIVES WHICH MUST BE MET AND HOW OBJECTIVES ARE MET FOR DAY LAUNCHES AND NIGHT LAUNCHES. REPORT TO THE PRCB. DEFER - 11/18/04 SSP PRCB PRESENTER(S): TBD ----------

S062343 ACTIONS ASSIGNED FROM THE JUNE 9, 2004 SPACE JSC-MS FLIGHT LEADERSHIP COUNCIL JSC-MS/2-1 USING PREVIOUS ORB FLT HISTORY, DEVELOP & VALI- JSC-MV/2-2 DATE CRITERIA FOR DETERMINING WHEN DISPOSITION OF DAMAGE OR SUSPECTED DAMAGE TO THE ORB TPS REQUIRES ADDITIONAL, HIGHER RESOLUTION, ON-ORBIT INSPECTION, DETERMINING WHEN AN ON-ORBIT REPAIR OF THE TPS MUST BE ATTEMPTED, & DETERMINING READINESS TO COMMIT TO THE DEORBIT BURN AFTER A TPS ON-ORBIT REPAIR HAS BEEN ACCOMPLISHED. REPORT TO THE PRCB. DEFER - 10/29/04 SSP PRCB PRESENTER(S): JSC-EA4/G. GAFKA ----------

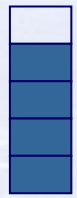
This is you!

Make it count!

S062375 BASELINE SHUTTLE SYSTEM INTEGRATION PLAN JSC-MS (SIP) FOR PRE-LAUNCH AND ASCENT DEBRIS CERTIFICATION WITHDRAWN PRESENTER(S): JSC-MS----------

S062383 EVA IR CAMERA JSC-MV JSC-MV/1-1 SUBMIT A SUPERSEDING CR TO ADDRESS FUNDING REQUIREMENTS AND STANDARD DEVELOPMENT SCHEDULE FOR THE EVA INFRARED CAMERA. REPORT TO THE PRCB. DEFER - 10/29/04 SSP PRCB PRESENTER(S): TBD -

Conclusion

- **Technical Wizard Success Mandatory Requirements**
  - **"Hard" technical skills** 
  - **"Soft" People Skills** 
- **Leadership Success Mandatory Requirements**
  - **"Hard" technical skills** 
  - **"Soft" People Skills** 
- **Success =**
  - **Loving what you do today (adding recognized value),**
  - **Knowing what you want to do tomorrow (adding recognized value),**
  - **Knowing how to get there,**
  - **Enjoying the journey along the way.**

I wish you your own personal situational success! Thank you!