Houston…You Have a Problem, or

Astronaut Dr. Charles J. Camarda has uncovered a recurring cause of accidents that no one has articulated yet—loss of a research culture that places a premium on learning and the quest for knowledge and what that means. He shows how to develop high-performing teams and networks of such research teams to solve anomalies rapidly, which can help prevent catastrophes in complex high-risk/high-reliability organizations.

Astronaut **DR. CHARLES J. CAMARDA** is an inventor, author, educator, and internationally recognized invited speaker on subjects related to engineering, engineering design, innovation, safety, organizational behavior, and education. He has over 60 technical publications, holds 9 patents, and has over 20 national and international awards.

Dr. Camarda is a NASA veteran with over 22 years of experience as a research engineer, 18 years as a NASA Astronaut who flew on STS-114, the return-to-flight mission following the Columbia disaster; and 13 years as a Senior Executive holding many positions within NASA.

He is an adjunct professor at several universities, has developed an innovative conceptual engineering design pedagogy called ICED which he has taught to NASA engineers, and which forms the basis for his 501 (c)(3) educational nonprofit called the Epic Education Foundation which he founded to democratize STEM/STEAM education for students of all ages around the world.

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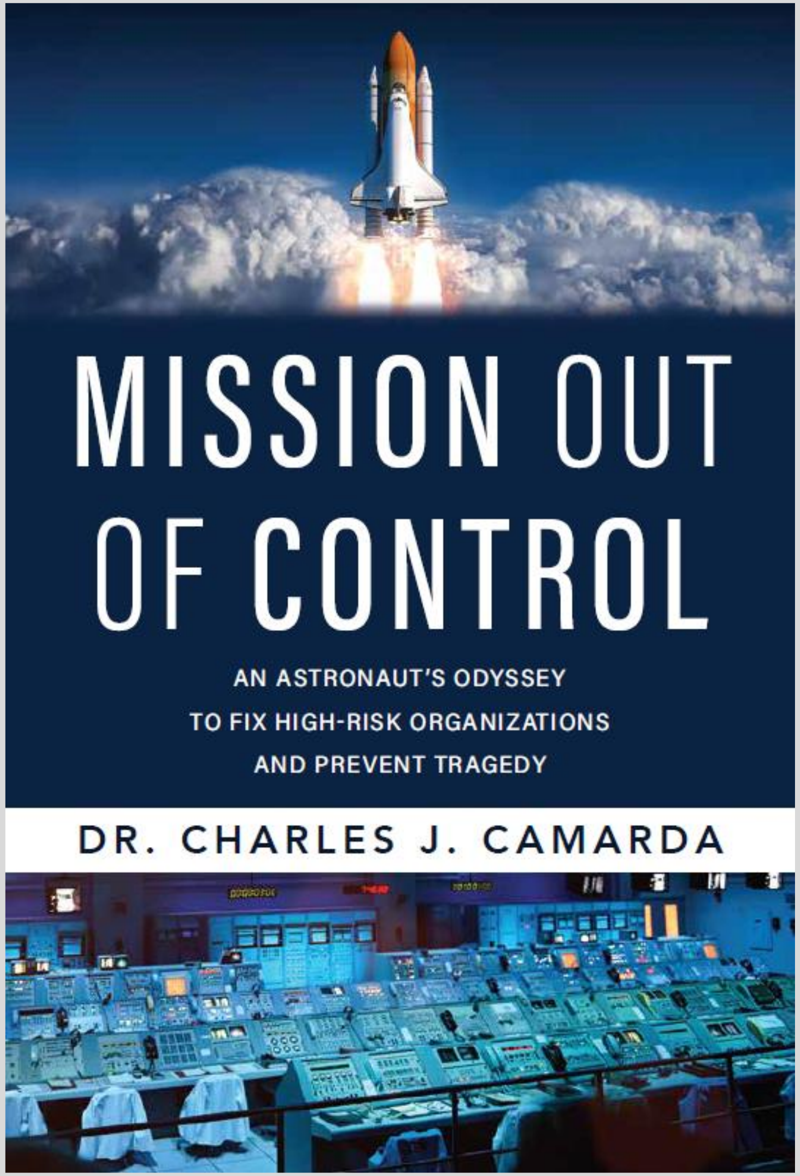
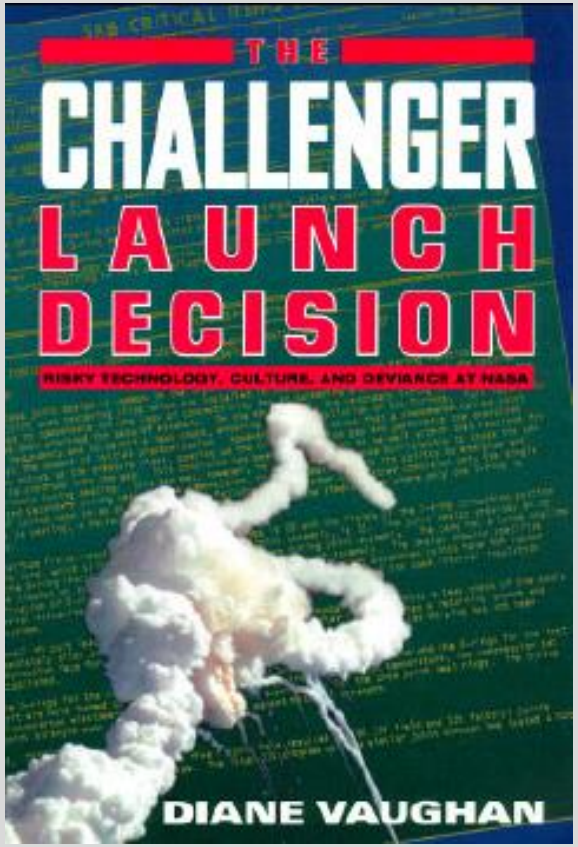
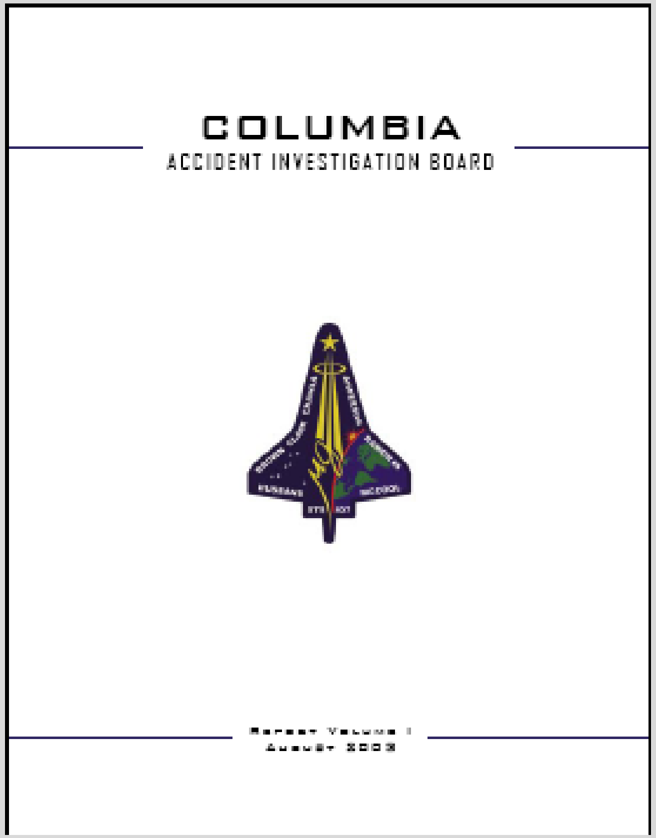


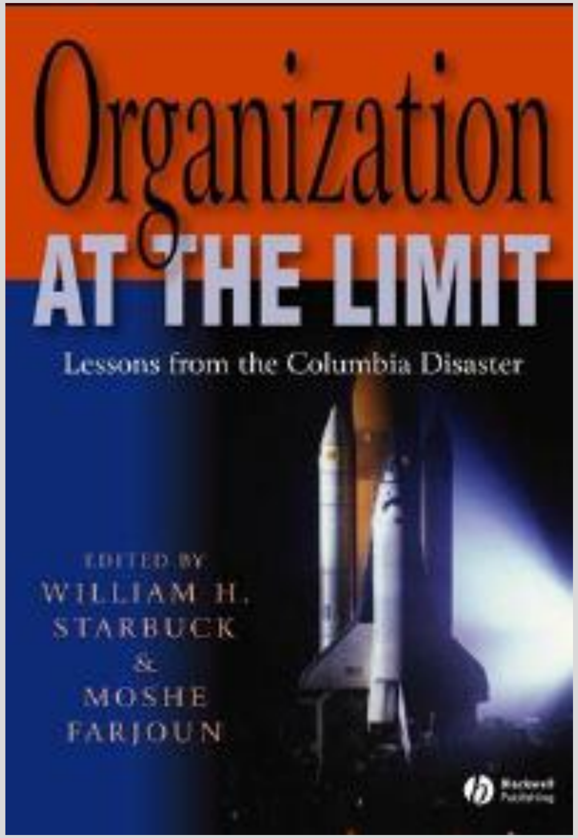
Columbia Tragedy


BROWN CLARK CHAWLA ANDERSON RAMON
HUSBAND
MCCOOL
STS 107

Accident References

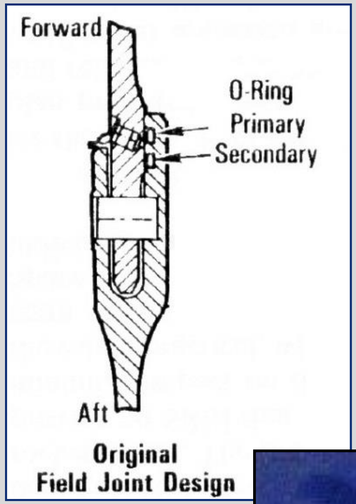






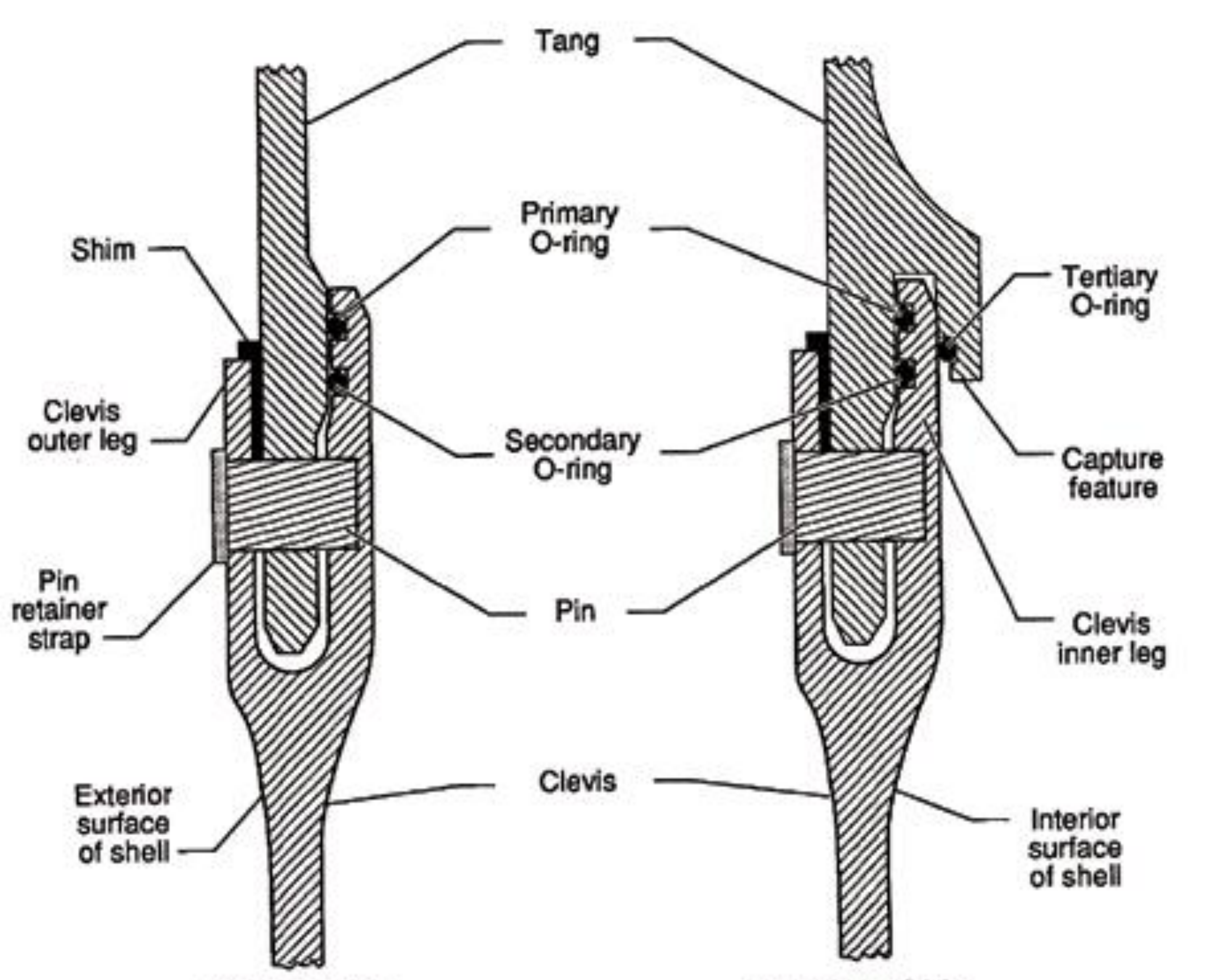
Challenger: The problem was the joint, not the O-Ring

- January 28, 1986, the Space Shuttle Challenger explodes 73 seconds into its launch, killing all seven crew members
- Investigation reveals that a solid rocket booster (SRB) joint failed, allowing flames to impinge on the external fuel tank
- Mark Salita model was woefully inadequate and not physics based
- Really a Joint deformation problem



- Liquid hydrogen tank explodes, ruptures liquid oxygen tank
- Resulting massive explosion destroys the shuttle

Challenger: The solution was a new field-joint design



(a) Original joint.

(b) Redesigned joint.

Columbia : *One of the first times culture was viewed as one of the primary causes of an accident*

- NASA had received painful lessons about its culture from the Challenger incident
- CAIB found disturbing parallels remaining at the time of the Columbia incident
- The Crater model was woefully inadequate and not physics based

"In our view, the NASA organizational culture had as much to do with this accident as the foam." *CAIB Report, Vol. 1, p. 97*

Crater Impact Damage Tool

$$P = \frac{(.0195)\,(L/d)^{.45}\,(d)\,(\rho_p)^{.27}\,(V-V^*)^{.67}}{(S)^{.25}\,(\rho_t)^{.17}} \qquad (1)$$

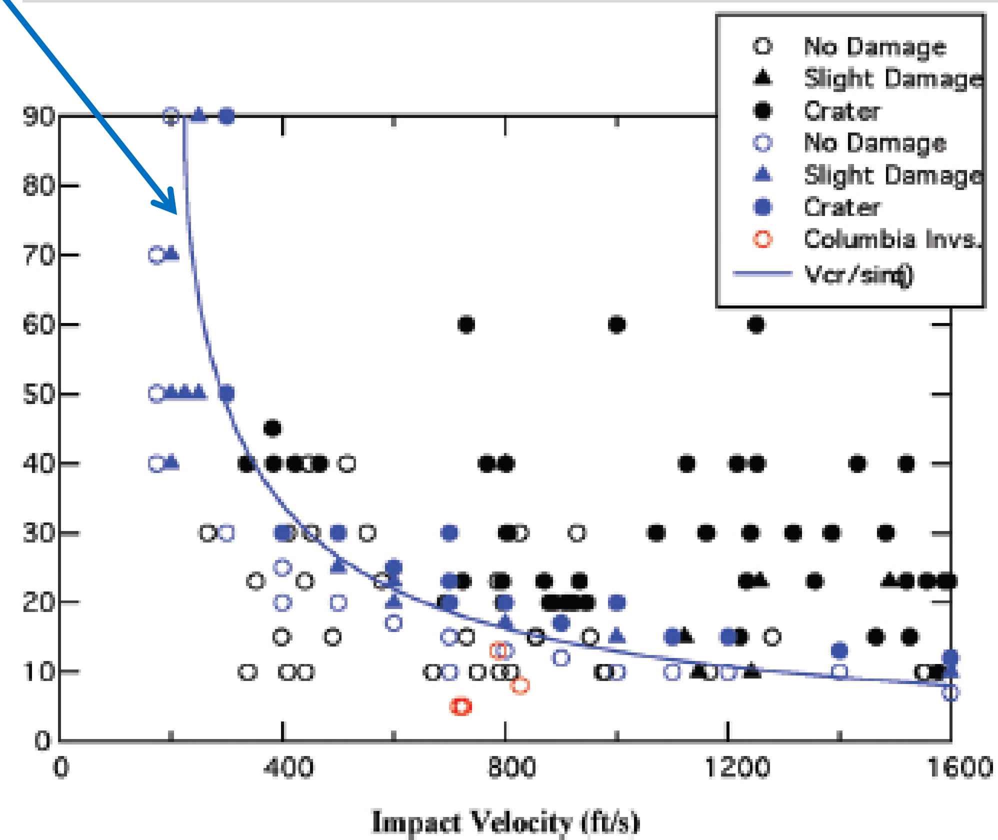
where: P = penetration depth
L = particle length
d = particle diameter or thickness
V = particle normal velocity
V^* = threshold velocity to break coating
S = tile compressive strength
ρ_p = particle density
ρ_t = target density
0.0195 = empirical Constant

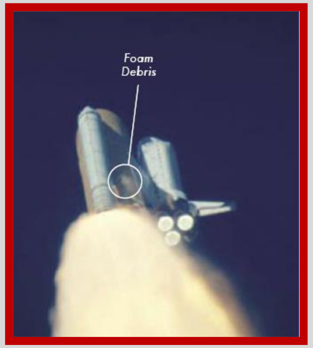
Foam Test Projectile Sizes Varied From: .21 to 3 in^3

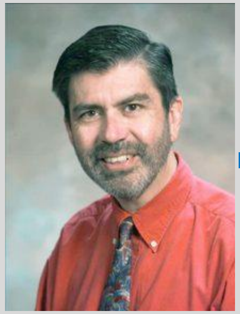
Actual Foam Debris size: 1290 in^3

Only 50 test data points

Large Scatter in Test Data







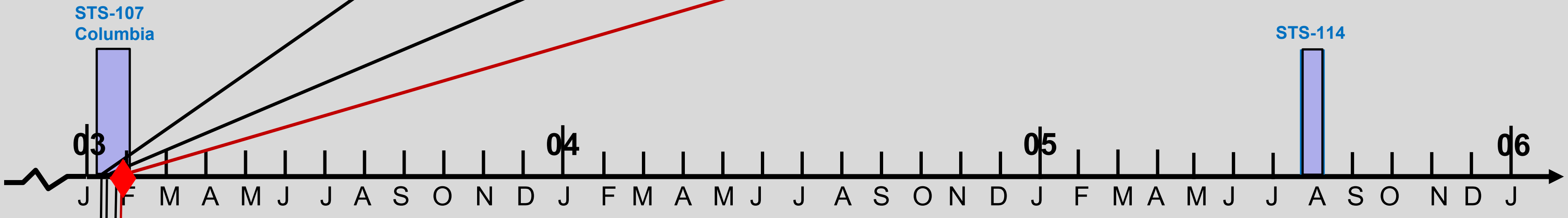
Rodney Rocha
Shuttle Engineer

Linda Ham
MMT Chair

Paul Shack
Shuttle Chief Engineer

Cal Schomburg
Tile "Expert"

Mike Gordon
RCC "Expert"



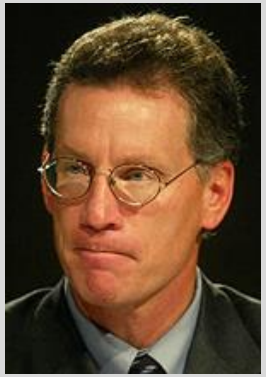
1/23/03 Paul Shack will not take Rocha's request forward "does not want to be a Chicken little

1/23/03 Mission Control email to crew – Foam no concern for RCC or tile damage"

1/22/03 Linda Ham cancels request to AF for imagery – "even if we saw something, we couldn't do anything about it. The Program didn't wand to spend the resources."

1/21/03 Rodney Rocha sends request for on-orbit imagery expressing concern

1/17/03 Intercenter Photo Working Group Photo analysis of foam strike



Ron Dittemore
Shuttle Program
Manager

Ralph Roe
Orbiter Project
Manager

With little corroboration, Shuttle management had become convinced that a foam strike was not and could not be a concern

It’s the Culture....Stupid!

Culture:

“The behavior patterns, arts, beliefs, institutions, and all other products of human work and thought, especially as expressed in a particular community or period” – The American Heritage Dictionary

Organizational Culture:

“Refers to the values, norms, beliefs, and practices that govern how an institution functions” – The CAIB Report Vol. 1

"NASA" Culture

There is no single "NASA" Culture:

- NASA is a composed of 10 Centers, each with its own individual "Culture(s)"
  - Research Centers, Human Space Centers (JSC, KSC, MSFC), Robotic Space Flight Centers (GSFC, JPL), etc.
- Within each Center you may have a mixture of various sub-cultures
  - (Research, operations (MOD), astronaut, engineering, program management, etc.)
- Diane Vaughn in her book entitled: "A Challenger Launch Decision" came very close in accurately describing the culture at one NASA Center (MSFC).
- Howard E. McCurdy in his book: "Inside NASA" describes NASA as a "Confederation of Cultures" (McCurdy: "Inside NASA")

Influences on Behavior and Decision Making

Cultural	Organizational	Social	Behavioral	Cognitive Biases[2]	Safety
Normalization of Deviance[1]	Hierarchical	Insular vs. Open	Arrogance	Confirmation bias	Lack of True Independence
Operations vs. R&D	Imbalance of power (Engineering vs Program)	Consensus driven	Silence	Sunken Cost	Tight Coordination
“Can-do”/”failure is not an option”	Bureaucratic Accountability[1]	Biased reward system	Inaction	Shared Cognitive Frame	Risk Analysis
Teamwork/consensus	Structural Secrecy[1]	“Expert”	Defensive	Overconfidence Bias	Decision Process
Working Group[1]	Complex, Tightly Coupled	Close Ranks and Attack	Reactive vs. Active	Recency Bias	Precursor Analysis
Culture of “Experts”	Strict Chain of Command	Poor Communication		Downplay Ambiguous Threats	Overreliance on Probability Risk Assessment (PRA)
Culture of Production[1]	Blind Adherence to Rules & Processes	Identity “Problem Solvers”	Psychological Safety[1,2]		
Lack of Critical Thinking	Rigid vs. Learning				
Success Syndrome[3]	Coordination Neglect – Lack of Systems Thinking				
Lack of Tolerance of Dissent	Lack of a Strong Research Culture				

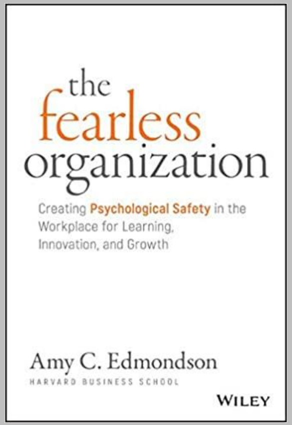
Research Engineering Culture

1 – Expressions used by Diane Vaughan in “The Challenger Launch Decision”
2 – Expressions used by Michael Roberto in “ Lessons from Everest – The Interaction of Cognitive Bias, Psychological Safety, and System Complexity”
3 – Expressions used by Henry Petroski in “Design Paradigms – Case Histories of Error and Judgment in Engineering”

Psychological Safety

A shared belief amongst individuals as to whether it is safe to engage in interpersonal risk taking in the workplace. An environment where employees feel safe to voice ideas, willingly seek feedback, provide honest feedback, collaborate, take risks and experiment. Able to engage in constructive conflict without fear of recrimination.

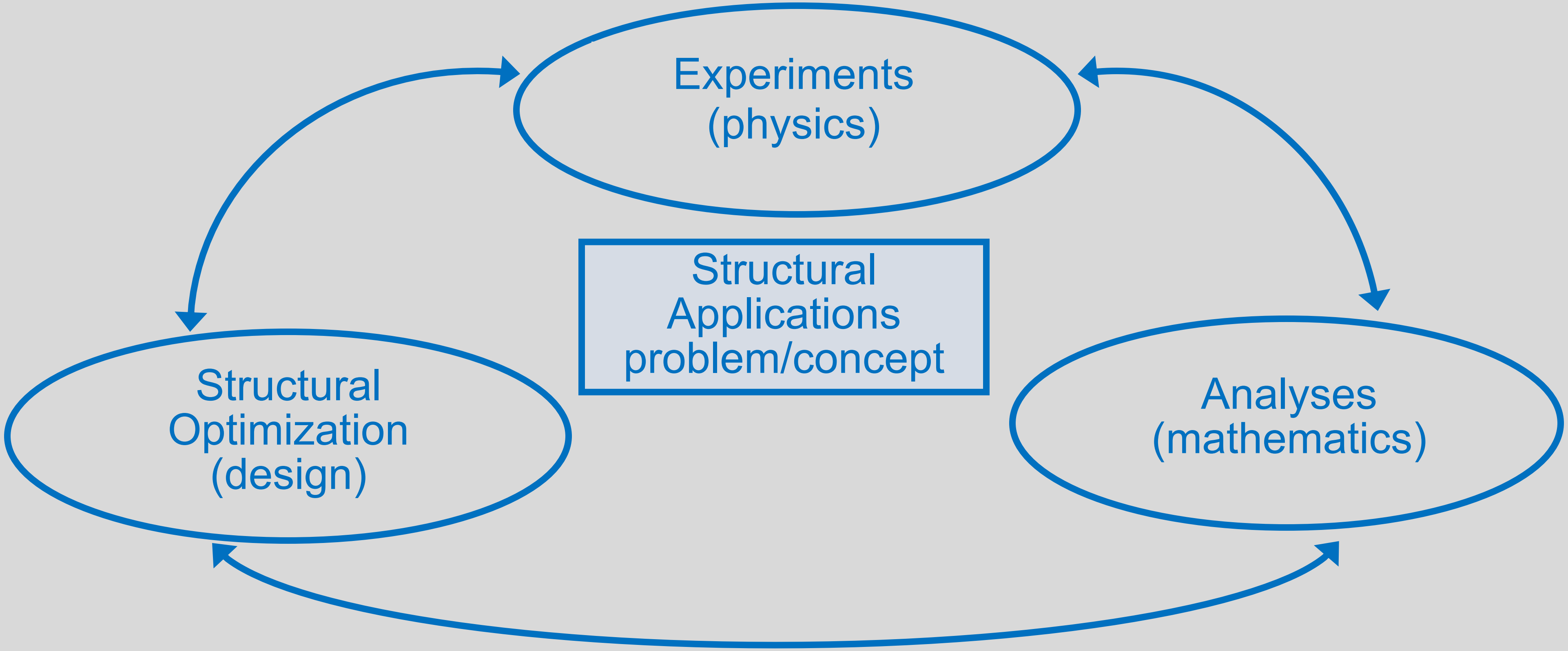
The Five Keys to a successful Google Team by Julia Rozovsky: "Psychological safety was far and away the most important of the five dynamics we found – it's the underpinning of the other four."



The Fearless Organization by Amy Edmondson: In a psychologically safe environment people are comfortable being themselves…sharing concerns…asking questions when they are unsure…reporting mistakes…sharing potentially game changing ideas." In essence, creating an environment that supports learning, innovation and growth!

Research Culture

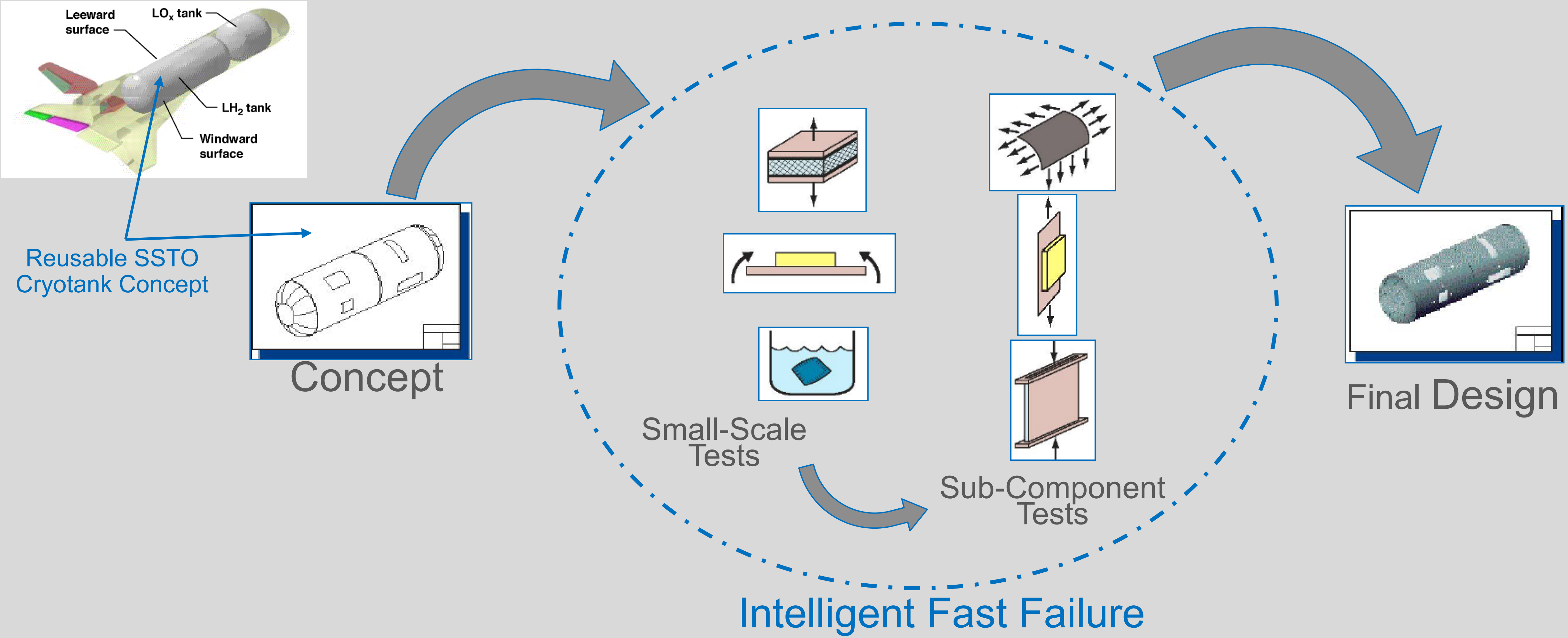
Construction of Knowledge



- Systematically vary parameters
- Understand true limits of performance
- Identify response/failure mechanisms

Construction of Knowledge (Cont'd)

Building Block Approach



Stepwise approach increasing complexity and rigor in both analysis and test:

- Test to failure
- Mature in ability to simulate reality

What Made NACA/Early NASA Great?

Research Culture

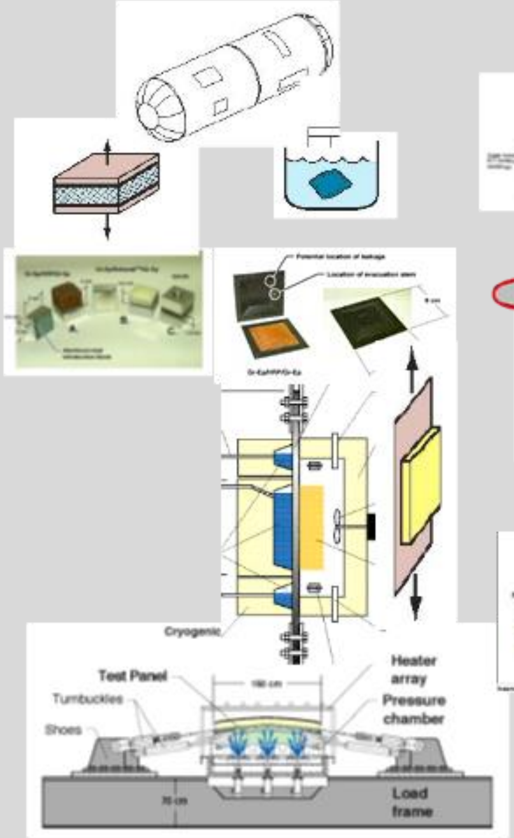
- Scientific Method & building block approach to construct knowledge
- Permission to “try and try again” – “Permission to Fail”
  - Intelligent Fast Failure – smart, fast, small, cheap, early, and often
- A Psychologically Safe environment
- Flat organizational structure
- A meritocracy, not a bureaucracy
  - Deference to the person with the knowledge/skill/expertise
- Transparent, open sharing of information, data, knowledge
- Encourage the maturation of competing ideas and concepts

Thermal Structures Branch



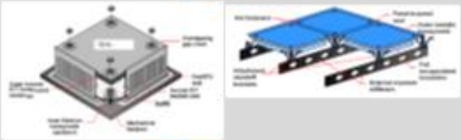


Cryogenic Tankage

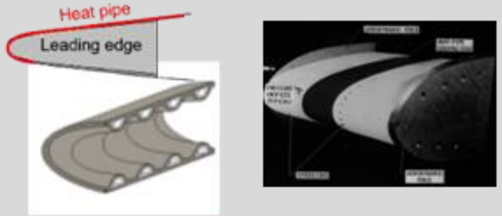


Thermal Protection Systems

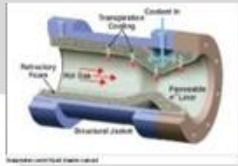
Passive



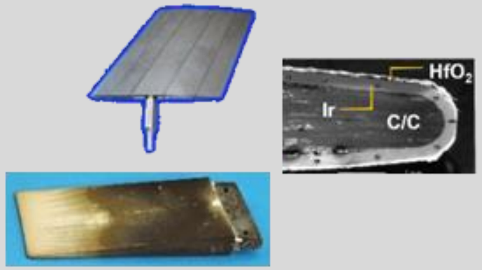
Semi-Passive

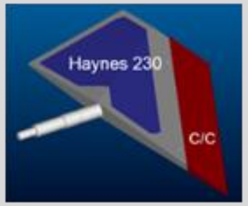


Cooled



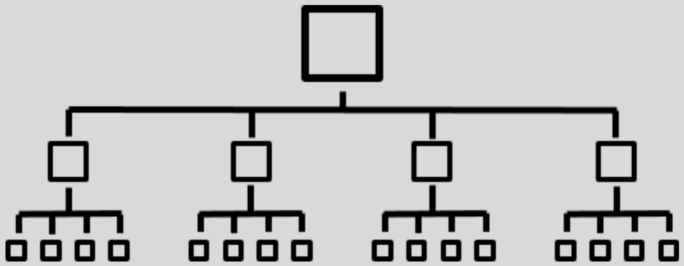

Hot Structure





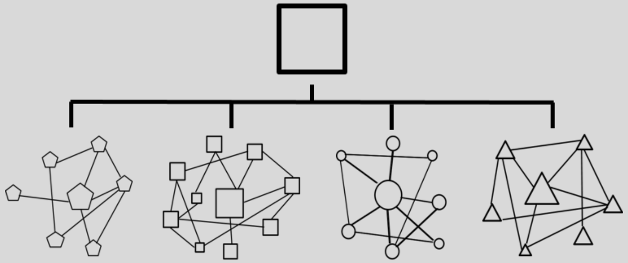
Organizational Structure

Command



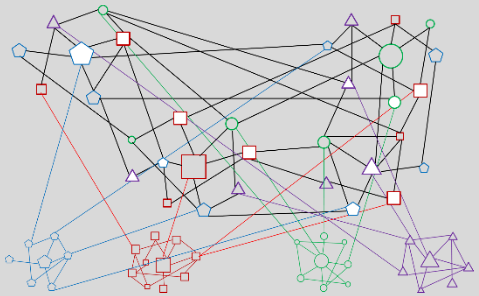
- Hierarchical, chain of command
- Information flows up and down
- Information not shared
- Slow response time

Command of Teams



- Single point of command for all teams
- Information not shared across teams
- Slightly better response time

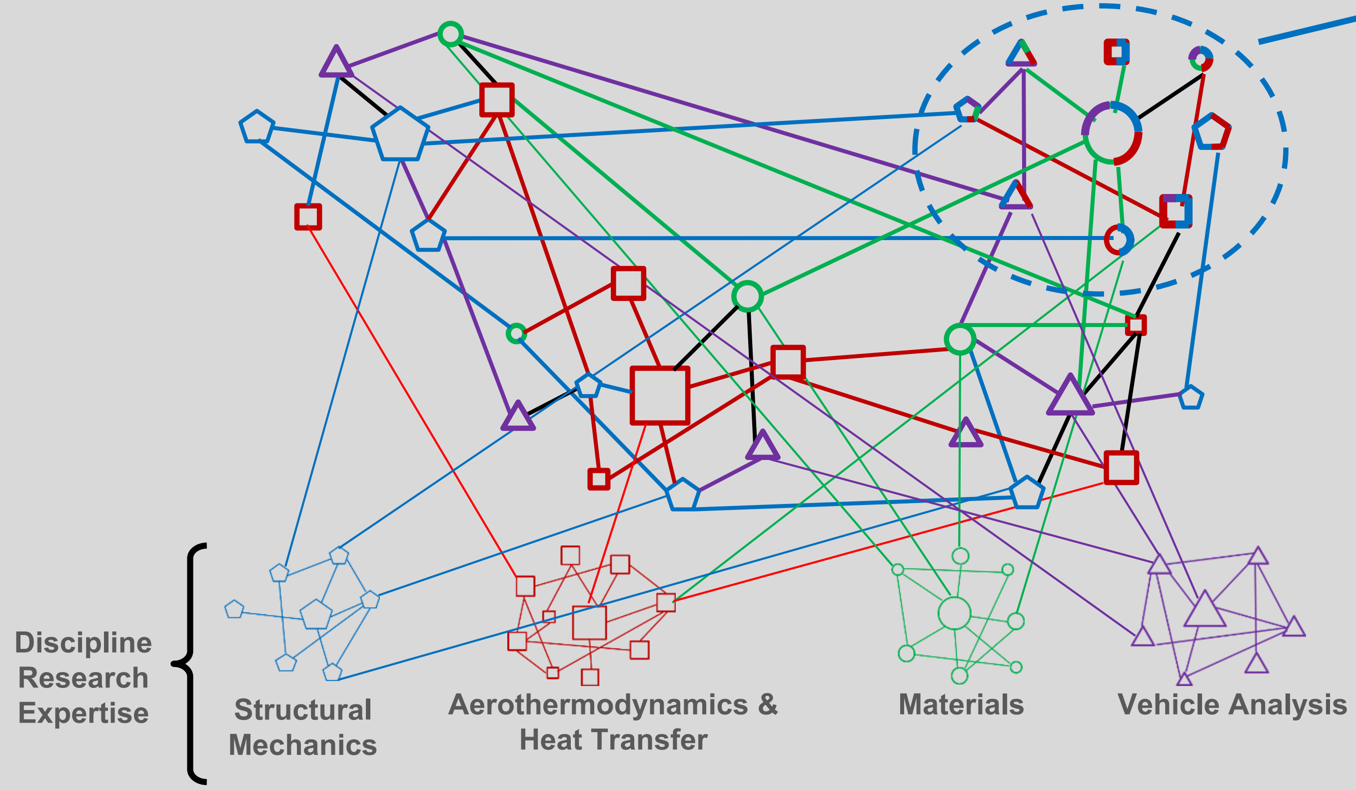
*Team of Teams



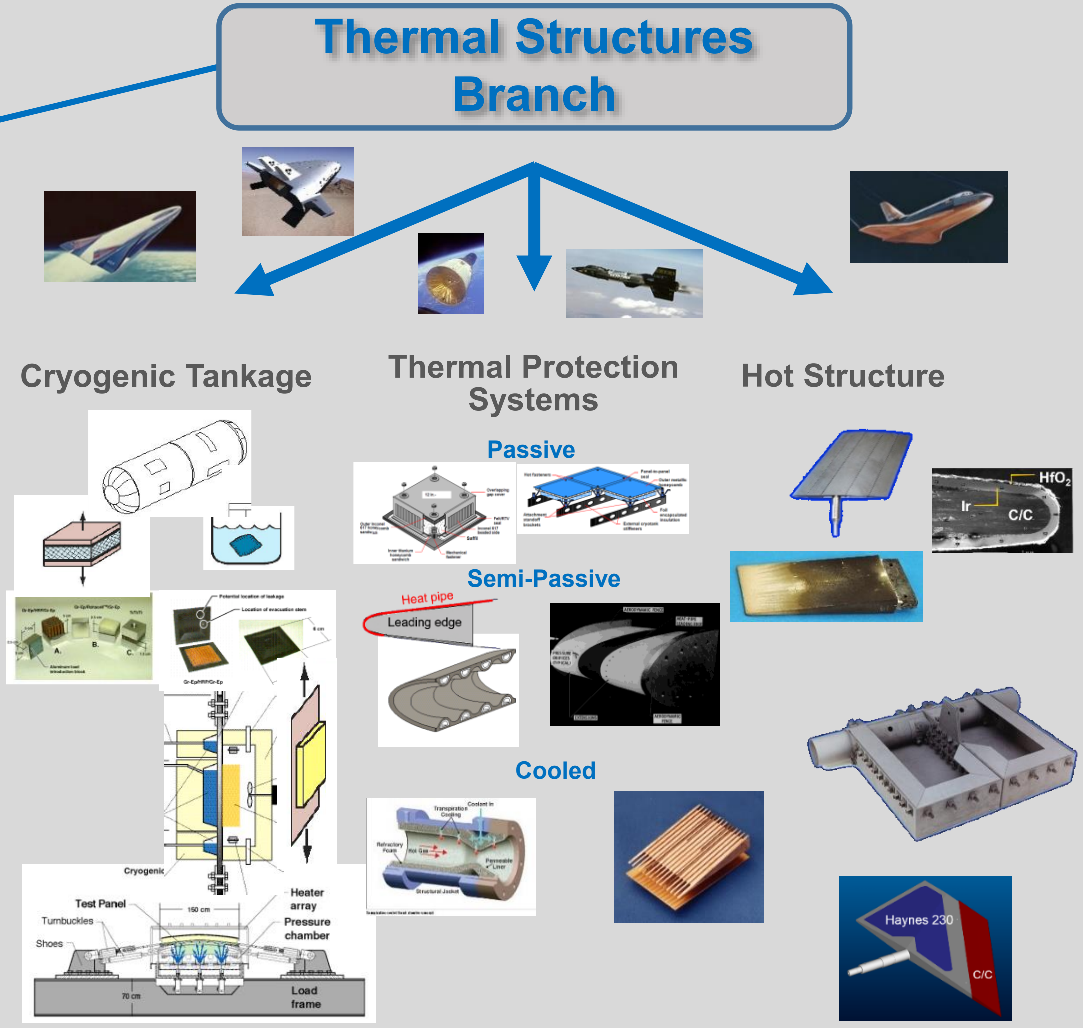
- Level, non-hierarchical org.
- Information flows up, down, across - transparent
- Rapid response time

**Team of Teams* by Gen. Stanley McChrystal

Friends of Charlie (FoC) Network



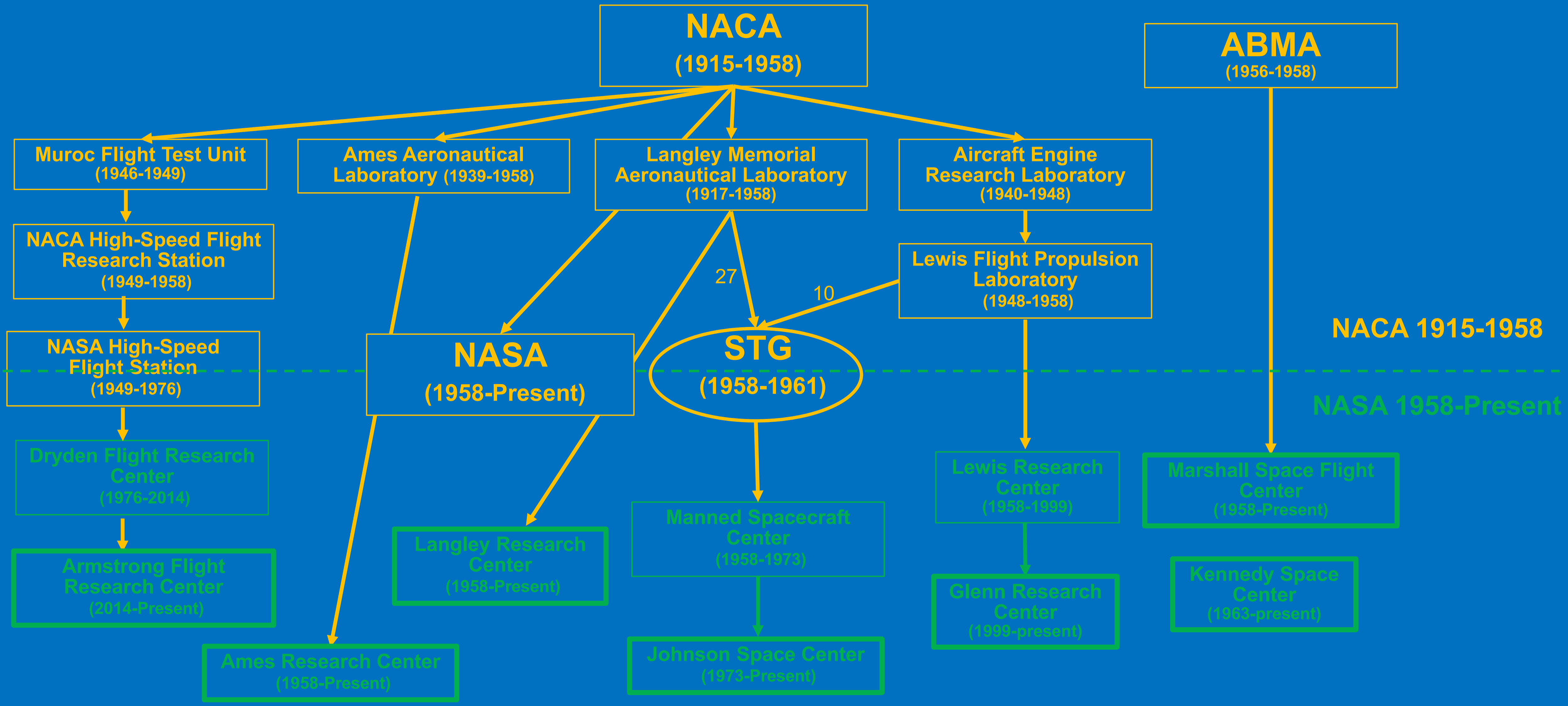
Definition of a “Research of Systems” Branch (Integrated Systems Research)



The Gradual Slide from a Research Culture

Boiling a Frog

Research: From NACA to NASA



Loss of a Research Culture

Things were so bad at NASA JSC when I was an Astronaut:

- Major problems with leaking cold plates in the ISS Destiny Laboratory Module
- Major structural design problems with the TVIS system on ISS
- Thermal stress chipping of SiC coating on RCC wing leading edges
- ET foam loss during liftoff

Building High-Performing Teams

How to Solve Complex, Tightly-Coupled, Interdisciplinary Problems

Characteristics of Teams which affect performance/behavior

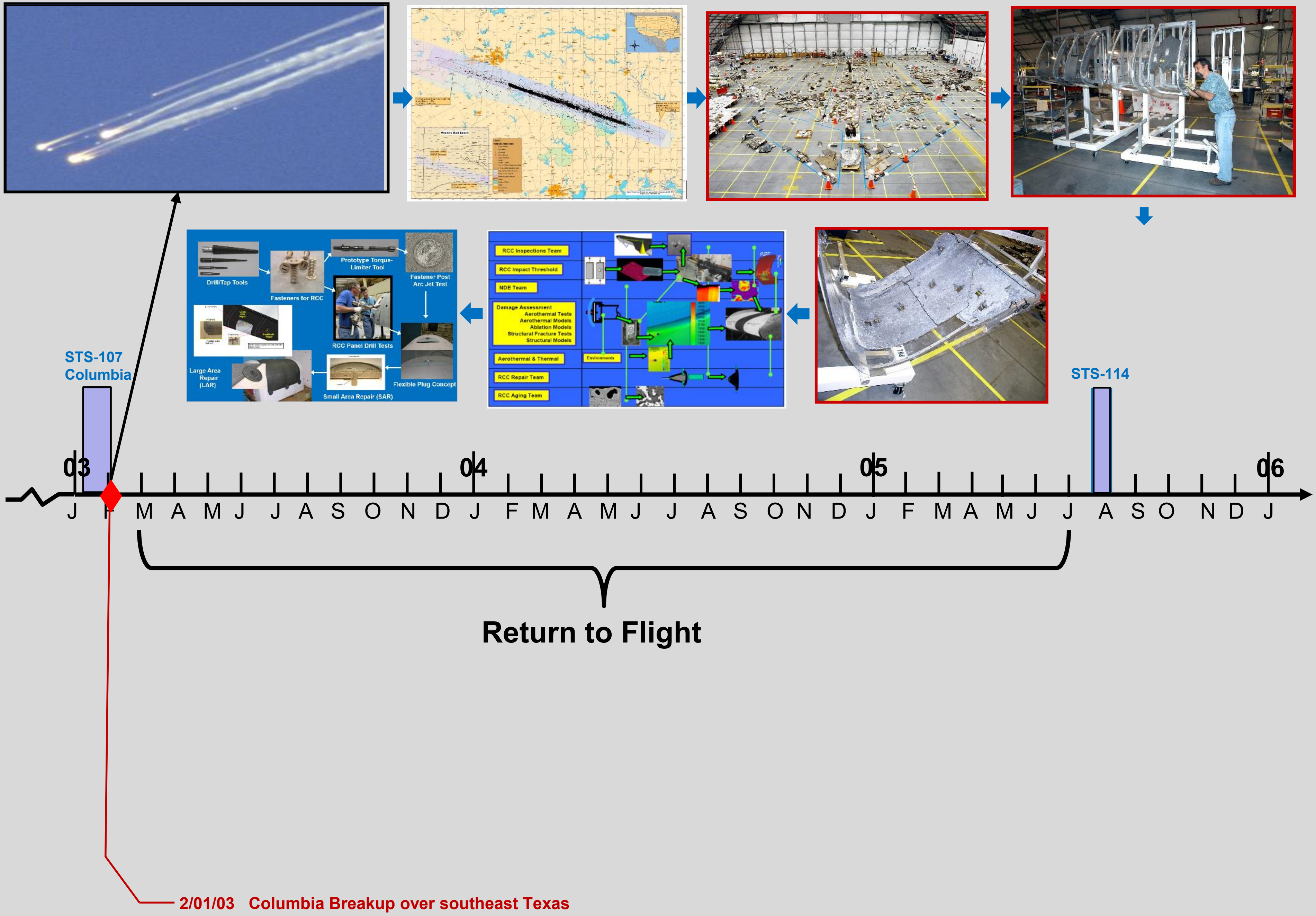
- **Level of Psychological Safety**
- Leadership style
  - Directive, collaborative/contemplative, flexible
- Cohesion (the "It" Factor)
- Communication
  - Open, transparent, siloed
  - Patterns: energy, engagement, & exploration
- Aversion/tolerance to risk & failure
- Resilience
- Diversity/Homogeneity
- Team Makeup
  - Skills, hobbies, passions, breadth/depth
- Environment
- Creativity
- Critical thinking
- Organizational structure & governance
- Overall team personality
  - Agreeableness, conscientiousness, emotional stability, extraversion, openness to experience
- Learning effectiveness
  - Collective intelligence, cognitive modes, learning styles
- Culture
- Trust
- Challenge/mission
  - "Epic-ness"
  - Meaningful

Determining the Technical Cause of the Columbia Accident

How to Solve Complex, Tightly-Coupled, Interdisciplinary Problems

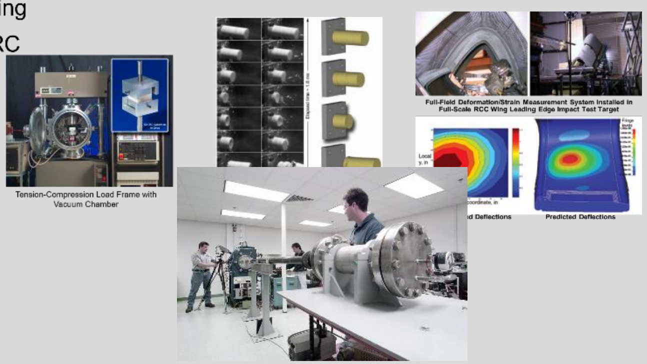
R&D Impact Dynamics Team

(RIDT)

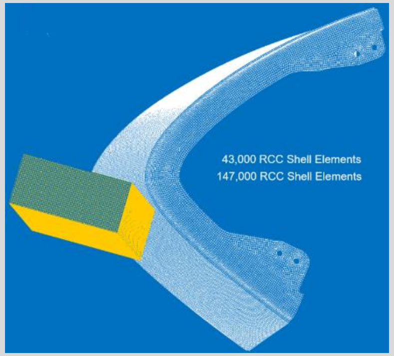


Drill/Tap Tools
Fasteners for RCC
Prototype Torque-Limiter Tool
Fastener Post Arc Jet Test
RCC Panel Drill Tests
Flexible Plug Concept
Small Area Repair (SAR)
Large Area Repair (LAR)
RCC Inspections Team
RCC Impact Threshold
NDE Team
Damage Assessment
Aerothermal Tests
Aerothermal Models
Ablation Models
Structural Fracture Tests
Structural Models
Aerothermal & Thermal
Environments
RCC Repair Team
RCC Aging Team
STS-107
Columbia
STS-114
03
04
05
06
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J
Return to Flight
2/01/03 Columbia Breakup over southeast Texas

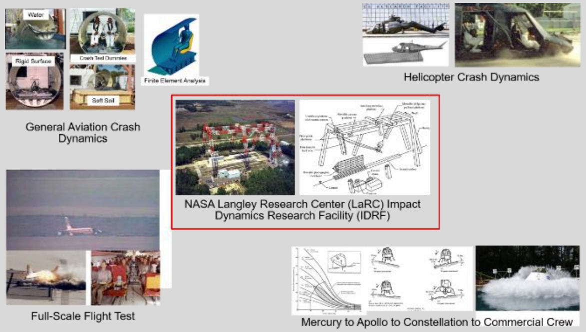
RTF Impact Dynamics Team



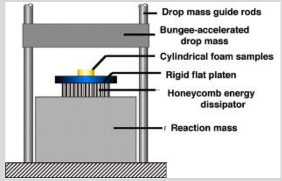
GRC

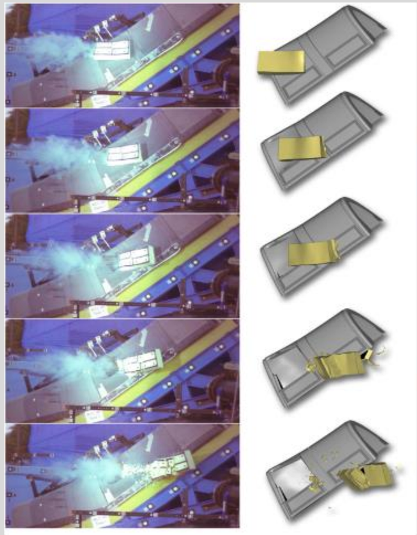


Boeing Philadelphia



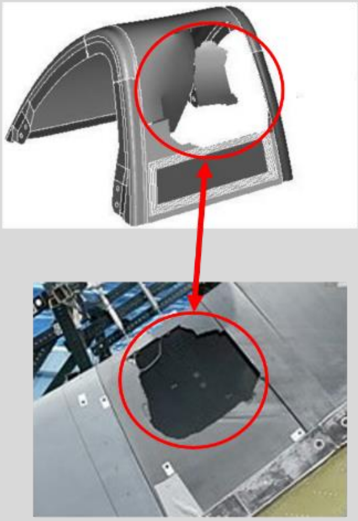
LaRC



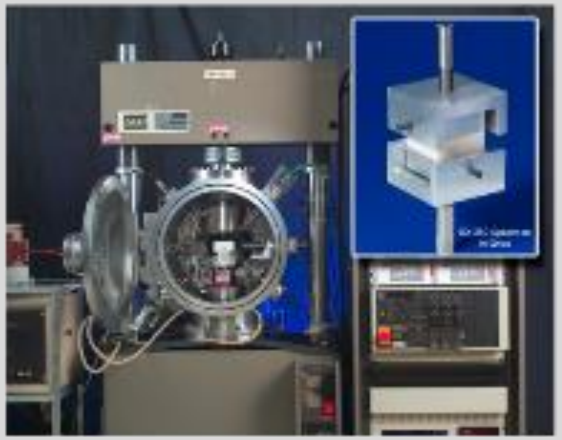


Time Lapse Comparison of Test and LS-DYNA Results for Panel 8R

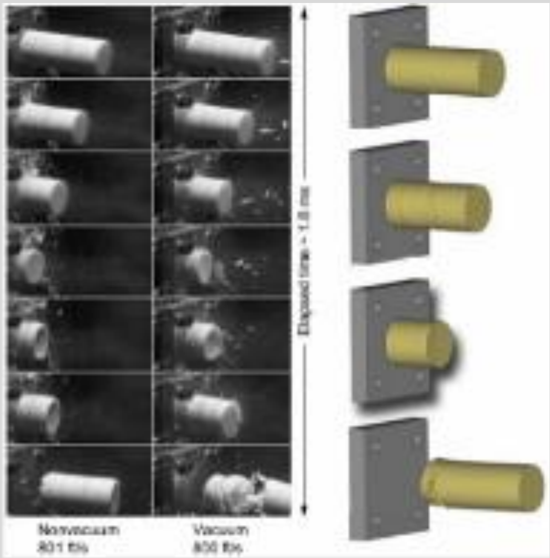
Full-Scale Ballistic Impact Test at SwRI



Blowup of Actual Vs Predicted Damage

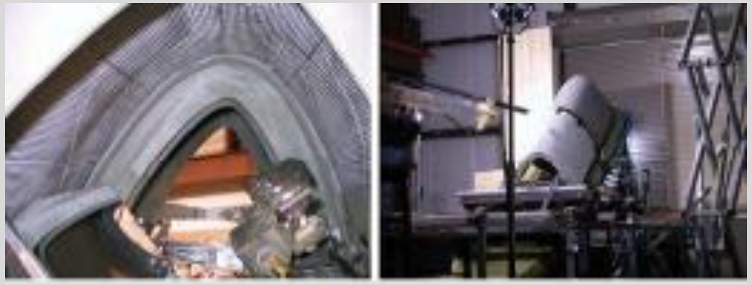


Tension-Compression Load Frame with Vacuum Chamber

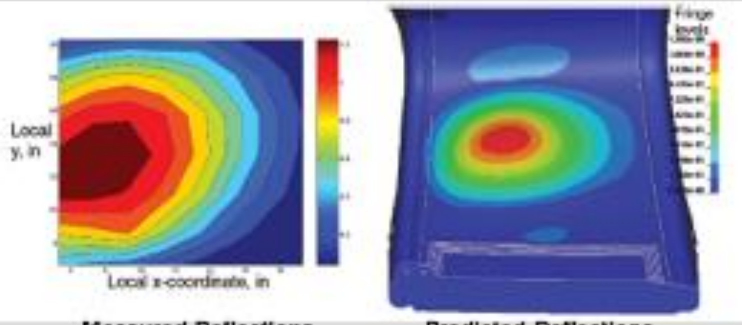


Analysis/Test Correlation of Ballistic Foam Impacts Vacuum/Nonvacuum

GRC

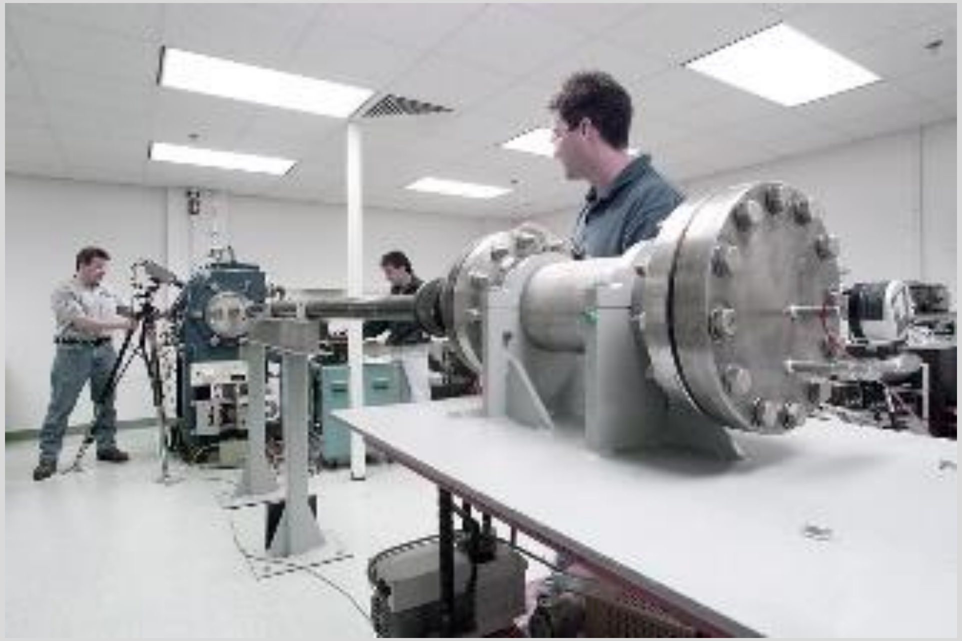


Full-Field Deformation/Strain Measurement System Installed in Full-Scale RCC Wing Leading Edge Impact Test Target



Measured Deflections

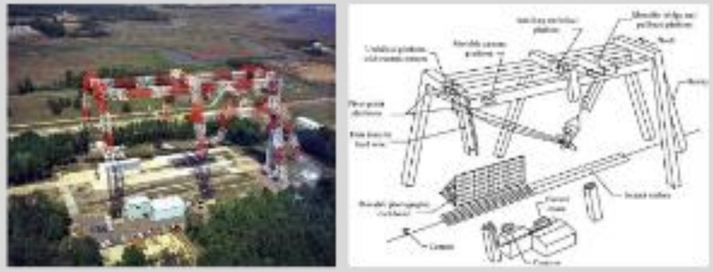
Predicted Deflections



LaRC

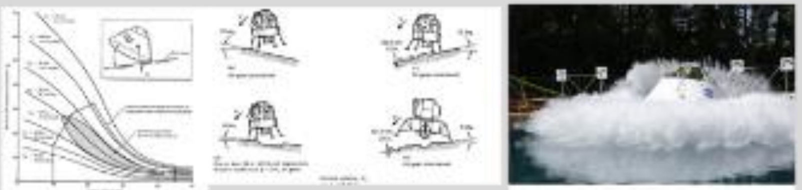
General Aviation Crash Dynamics

Helicopter Crash Dynamics

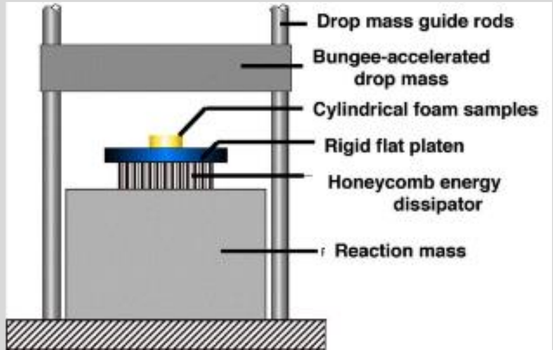


NASA Langley Research Center (LaRC) Impact Dynamics Research Facility (IDRF)

Full-Scale Flight Test

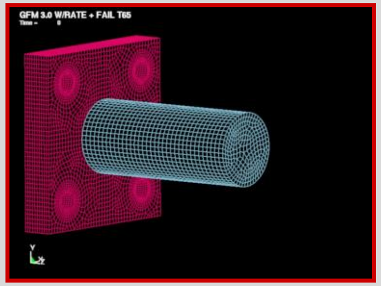


Mercury to Apollo to Constellation to Commercial Crew

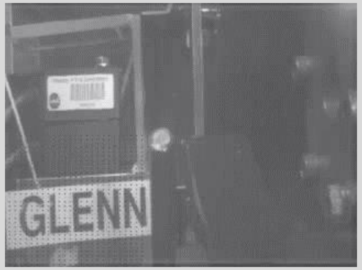


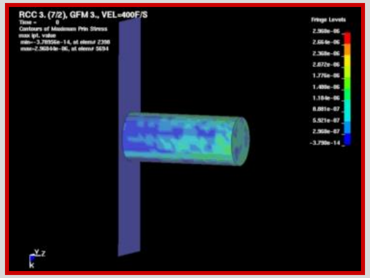
Failing Smart, Fast, Small Cheap, Early, and often

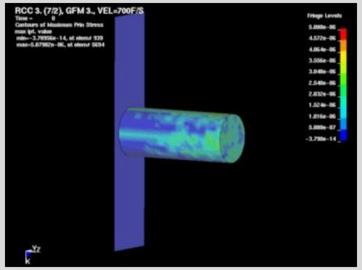
Using a Research-Based Building Block Approach



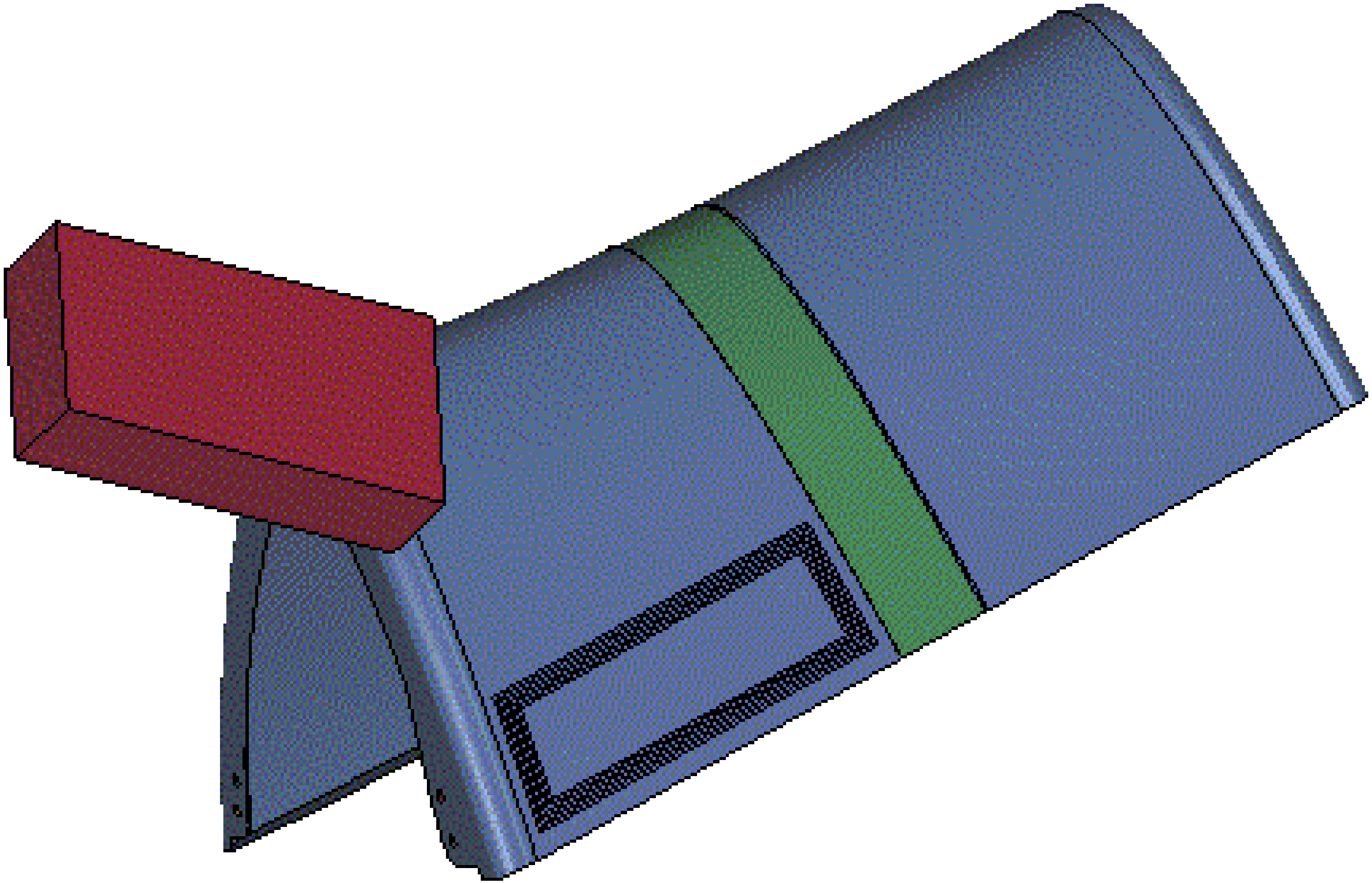
Understanding foam impact behavior





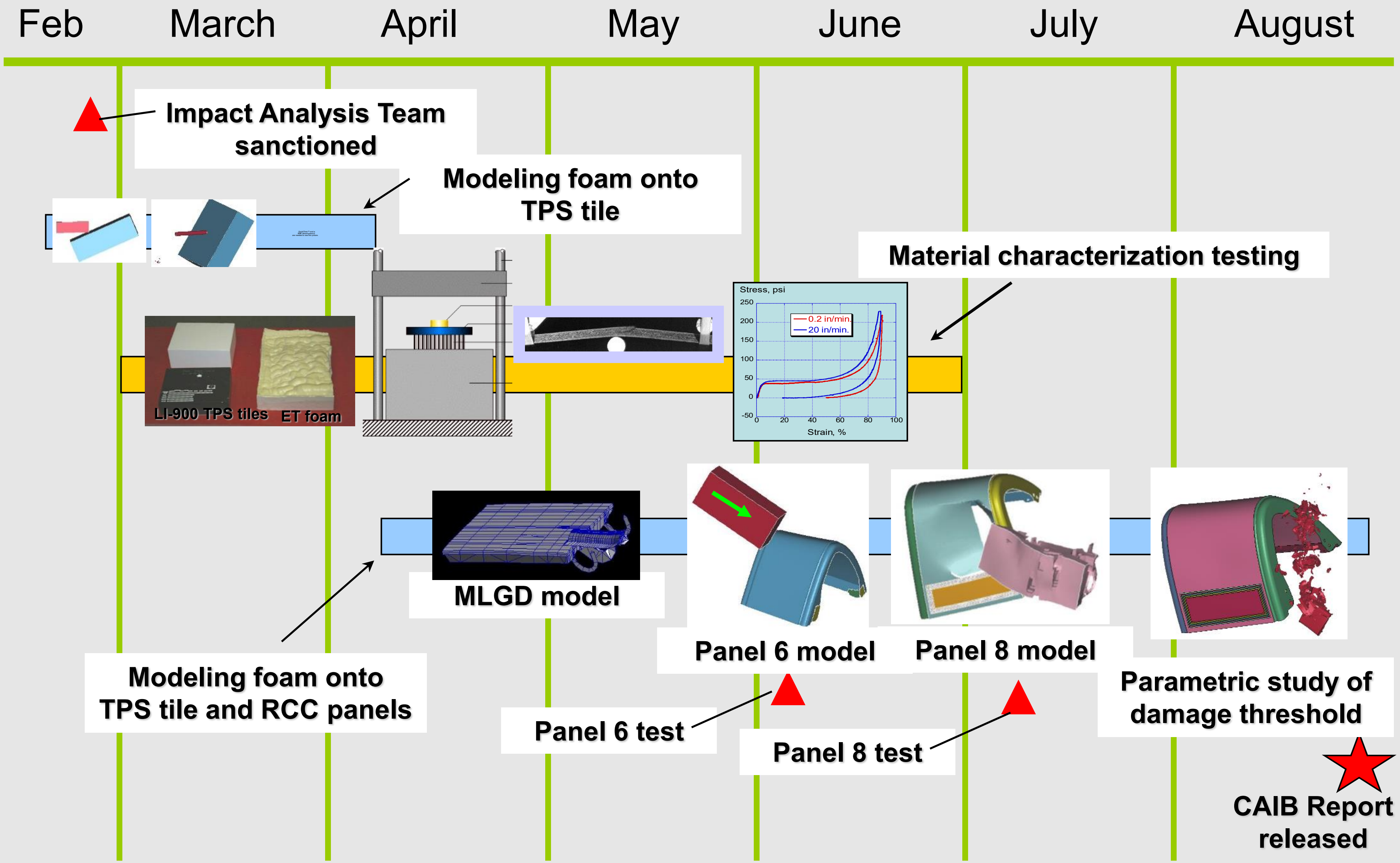


Understanding reinforced carbon-carbon (RCC) impact behavior



R&D Impact Dynamics Team

Significant Accomplishments in a Timely Manner



History of ET Foam Loss

MISSION	DATE	COMMENTS
STS-1	April 12, 1981	Lots of debris damage. 300 tiles replaced.
STS-7	June 18, 1983	First known left bipod ramp foam shedding event.
STS-27R	December 2, 1988	Debris knocks off tile; structural damage and near burn through results.
STS-32R	January 9, 1990	Second known left bipod ramp foam event.
STS-35	December 2, 1990	First time NASA calls foam debris "safety of flight issue," and "re-use or turn-around issue."
STS-42	January 22, 1992	First mission after which the next mission (STS-45) launched without debris In-Flight Anomaly closure/resolution.
STS-45	March 24, 1992	Damage to wing RCC Panel 10-right. Unexplained Anomaly, "most likely orbital debris."
STS-50	June 25, 1992	Third known bipod ramp foam event. Hazard Report 37: an "accepted risk."
STS-52	October 22, 1992	Undetected bipod ramp foam loss (Fourth bipod event).
STS-56	April 8, 1993	Acreage tile damage (large area). Called "within experience base" and considered "in family."
STS-62	October 4, 1994	Undetected bipod ramp foam loss (Fifth bipod event).
STS-87	November 19, 1997	Damage to Orbiter Thermal Protection System spurs NASA to begin 9 flight tests to resolve foam-shedding. Foam fix ineffective. In-Flight Anomaly eventually closed after STS-101 as "accepted risk."
STS-112	October 7, 2002	Sixth known left bipod ramp foam loss. First time major debris event not assigned an In-Flight Anomaly. External Tank Project was assigned an Action. Not closed out until after STS-113 and STS-107.
STS-107	January 16, 2003	*Columbia* launch. Seventh known left bipod ramp foam loss event.

Figure 6.1-7. The Board identified 14 flights that had significant Thermal Protection System damage or major foam loss. Two of the bipod foam loss events had not been detected by NASA prior to the Columbia Accident Investigation Board requesting a review of all launch images.

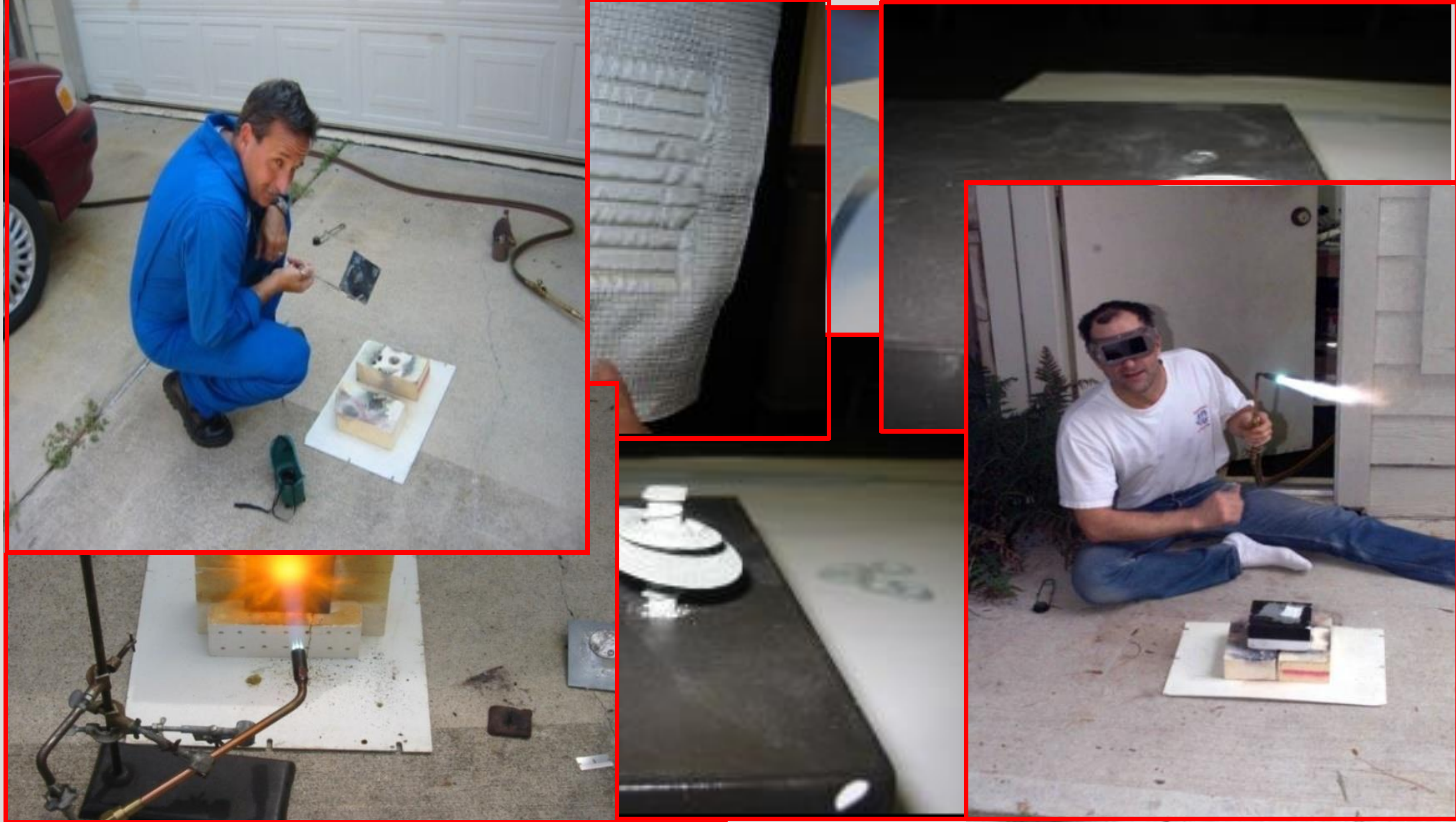
First known occurrence of Bi-Pod Foam Loss June 18, 1983

28 prior incidents of Bi-Pod Foam Loss

CAIB Report Vol. I

R&D On-Orbit Repair Team

(ROORT)



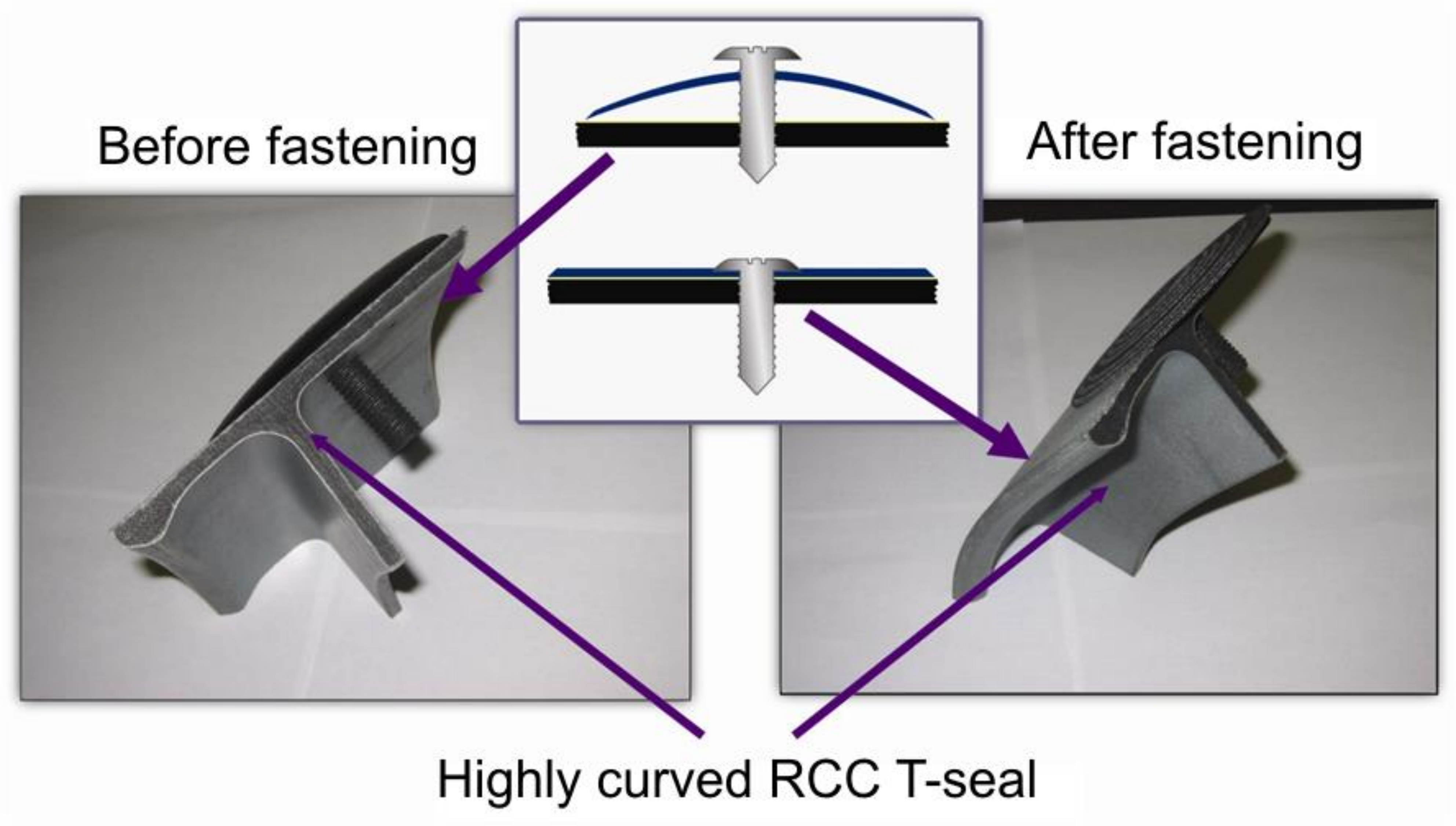
R&D On-Orbit Repair Teams

Phase I

Name	Organization	Area of Expertise
Donna Phillips	NASA LARC	Workshop facilitator
Aaron Matheson	ATK Thiokol	Material testing
Ali Yousefiani	Boeing HB	High temp. materials & processes
Brian Sullivan	MR&D	Materials/structures
Bruce Steinetz	NASA GRC	High temp. seals/TPS and turbine engines
Charlie Camarda	NASA JSC	Thermal structures, heat pipes, Crew
Clark Thompson	Boeing	EVA systems
David Glass	NASA LARC	High temp structures and materials, heat pipes
Don Curry	NASA JSC	Thermal protection systems – RCC material
Don Pettit	NASA JSC	Chemical engineering, Crew, EVA
Francesco Iannetti	Design Ideas, Inc.	Design concepts
James Reeder	NASA LARC	Material mechanics
Jim Nesbitt	NASA GRC	Oxidation, high-temperature coatings
Joel Alexa	Lockheed Martin	Plasma spray
John Koenig	SRI	Materials/testing
Ken Cooper	NASA MSFC	Fabrication non-metallics
Mike Gubert	MSFC/Sverdrup	Thermal protection system
Pete Hogenson	Boeing HB	M&P TPS
Peter Gnoffo	NASA LARC	Aerothermal environment
Steve Hales	NASA LARC	Metals and plasma spray
Steve Scotti	NASA LARC	Thermal structures
Suraj Rawal	Lockheed Martin	C-C/C-SiC materials; TPS passive/active
Tom Horvath	NASA LARC	Aerothermal environment
Wallace Vaughn	NASA LARC	C-C/C-SiC materials

Phase II

Flexible RCC Plug & Fastener Idea Demonstrated with Prototype



We were told it would be impossible to drill through reinforced carbon-carbon (RCC)…

RCC Drill Bits designed, fabricated, tested, certified and flown in one year

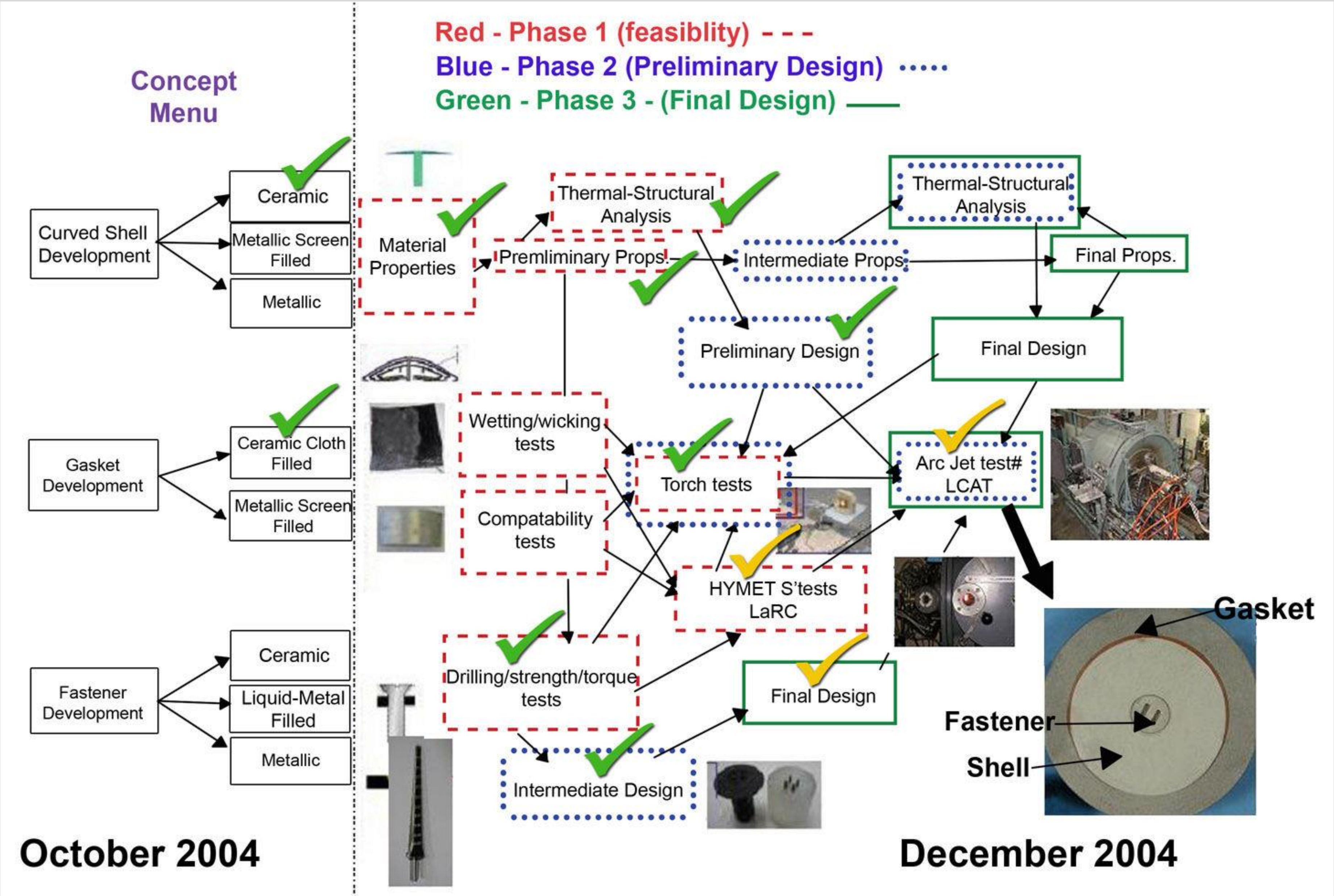
The “Right” Expert at the “Right” Time

Solved the On-Orbit Wing Leading Edge Repair Problem in Less Than One Year

Aerothermal expert, Dr. Peter Gnoffo, solved critical design issue in one day!

Complete set of RCC repair plugs ready for flight

Developing Strategies for Rapid Concept Development



Rapid Concept Development

Enhanced Creativity and Innovation

Drill/tap tools

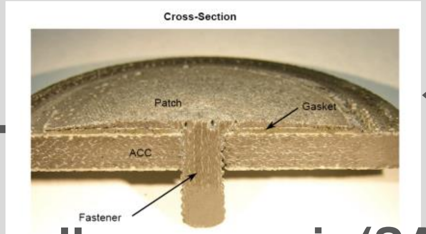
Fasteners for RCC

Prototype torque-limiter tool

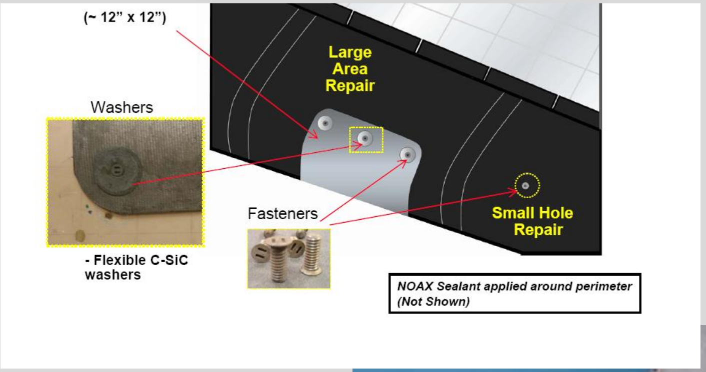
Fastener post arc jet test

RCC panel drill tests

Flexible plug concept



Small area repair (SAR)



Large area repair (LAR)

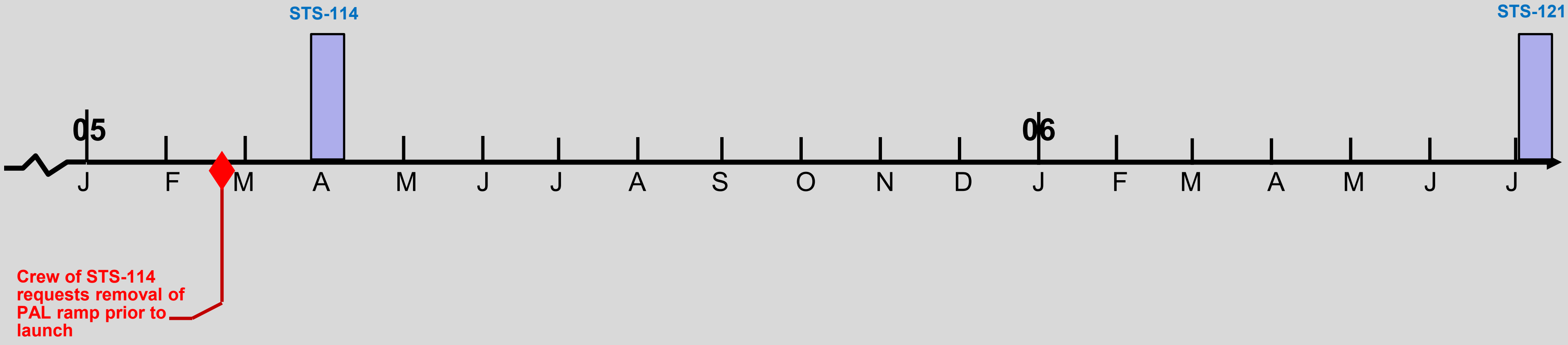
Cosmetic Fixes and Two Near Misses

Did NASA Learn Its Lesson?

STS-114
Return to Flight

PRA Calculation of PAL Ramp Threat
Post-Flight of STS-114 = 1/26

STS-121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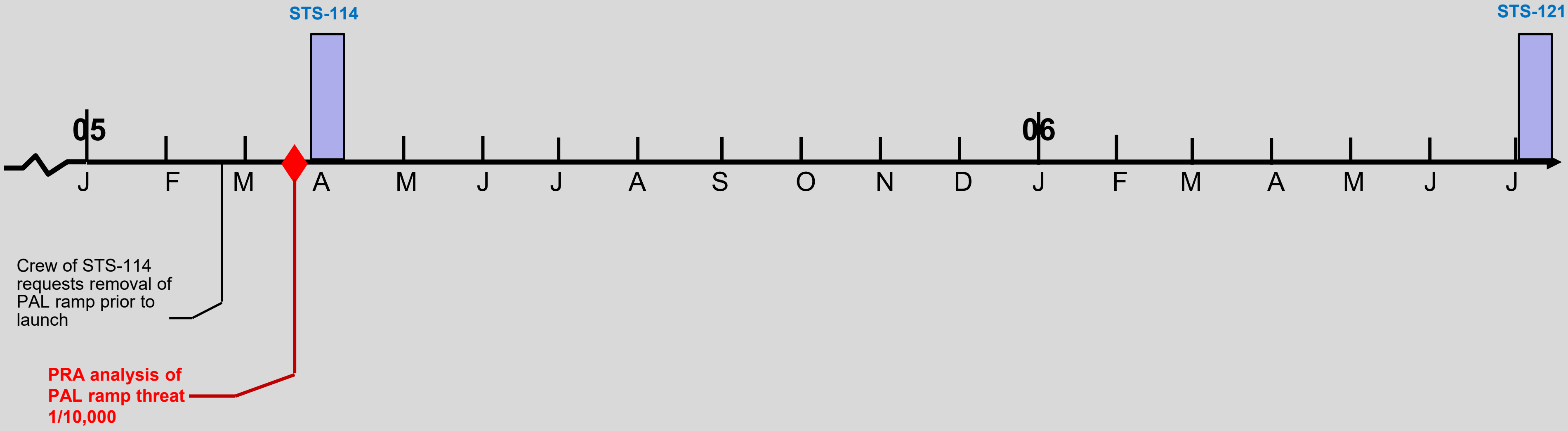
J F M A M J J A S O N D J F M A M J J
Crew of STS-114 requests removal of PAL ramp prior to launch



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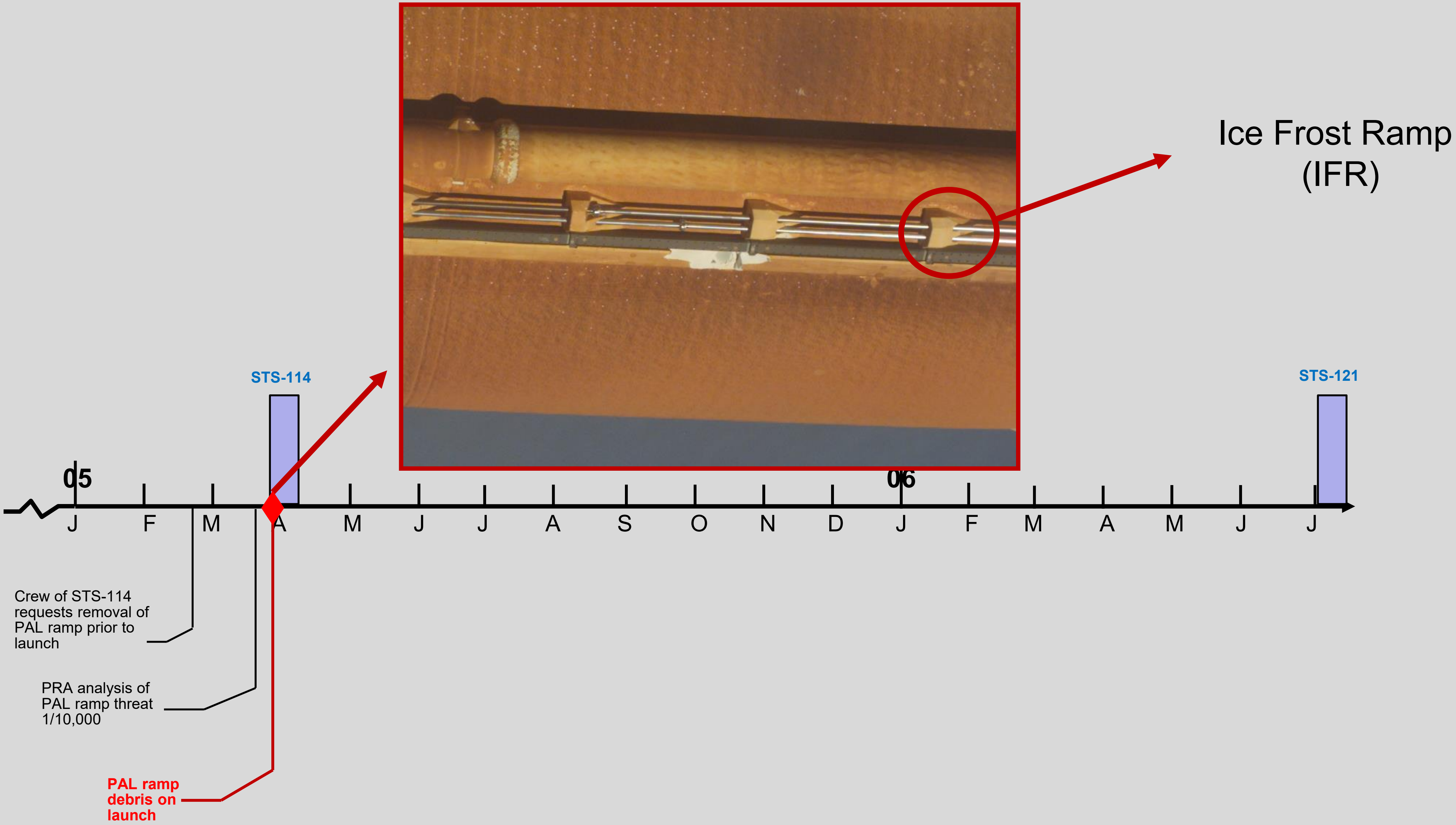
Crew of STS-114 requests removal of PAL ramp prior to launch
PRA analysis of PAL ramp threat 1/10,000



Ice Frost Ramp
(IFR)
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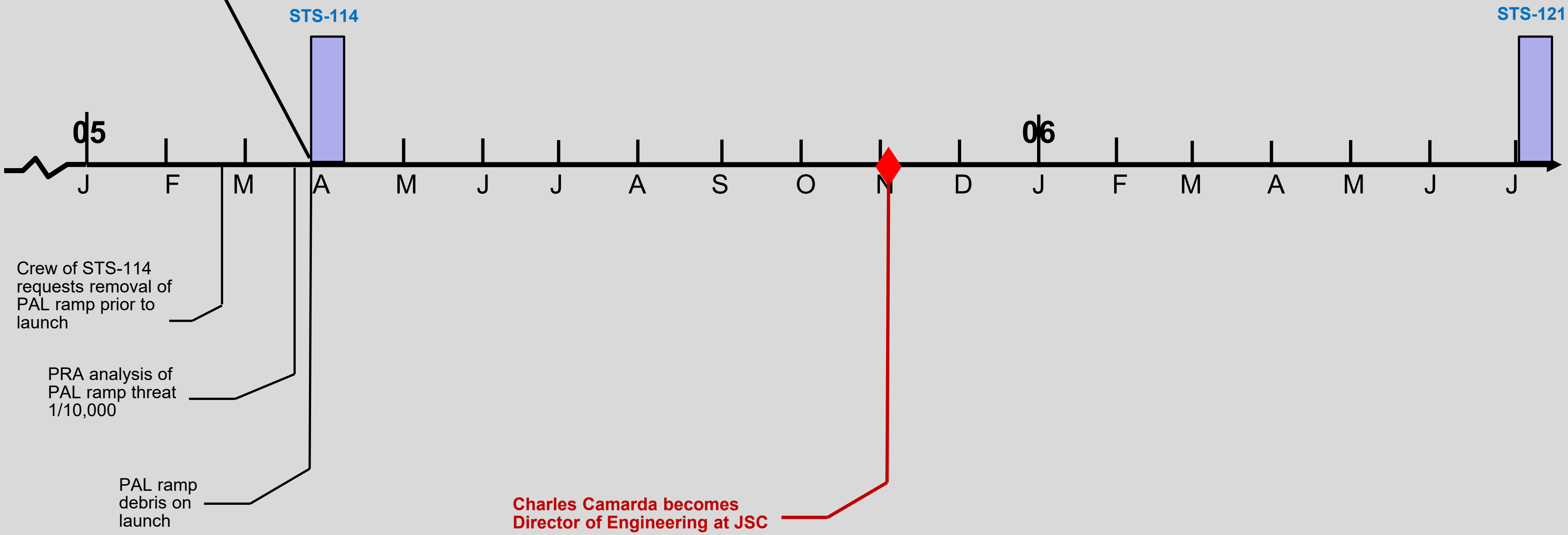
Crew of STS-114 requests removal of PAL ramp prior to launch
PRA analysis of PAL ramp threat 1/10,000
PAL ramp debris on launch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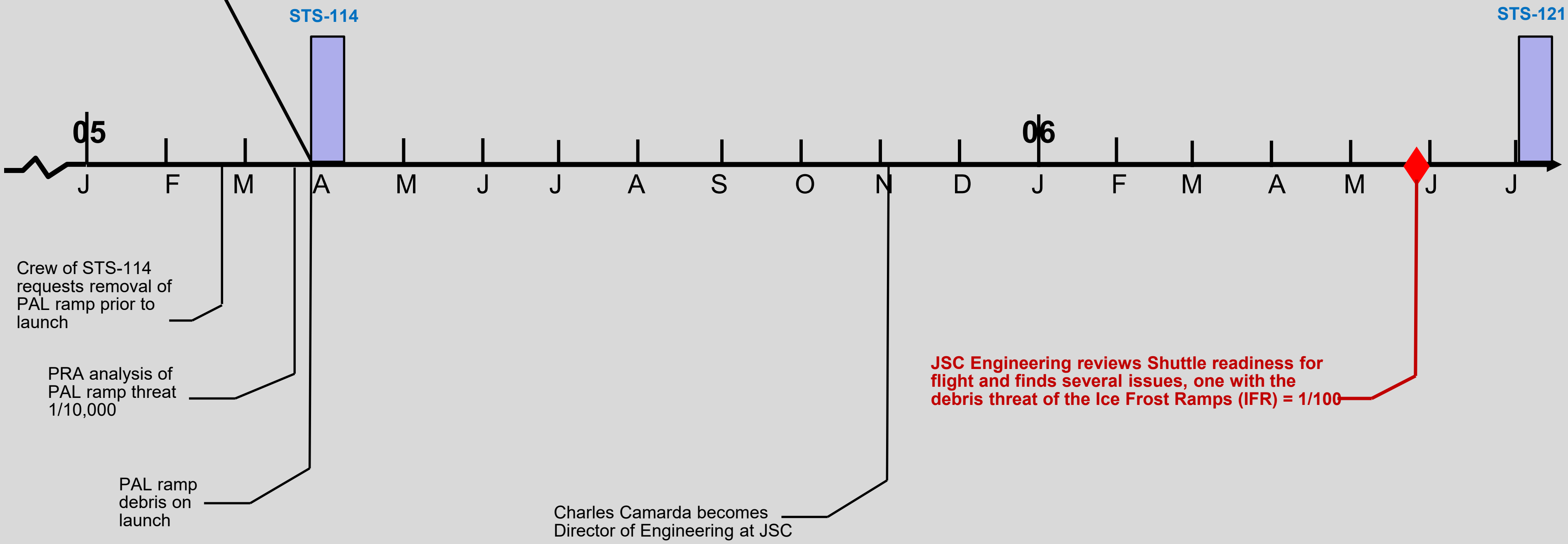
Crew of STS-114 requests removal of PAL ramp prior to launch
PRA analysis of PAL ramp threat 1/10,000
PAL ramp debris on launch
Charles Camarda becomes Director of Engineering at JSC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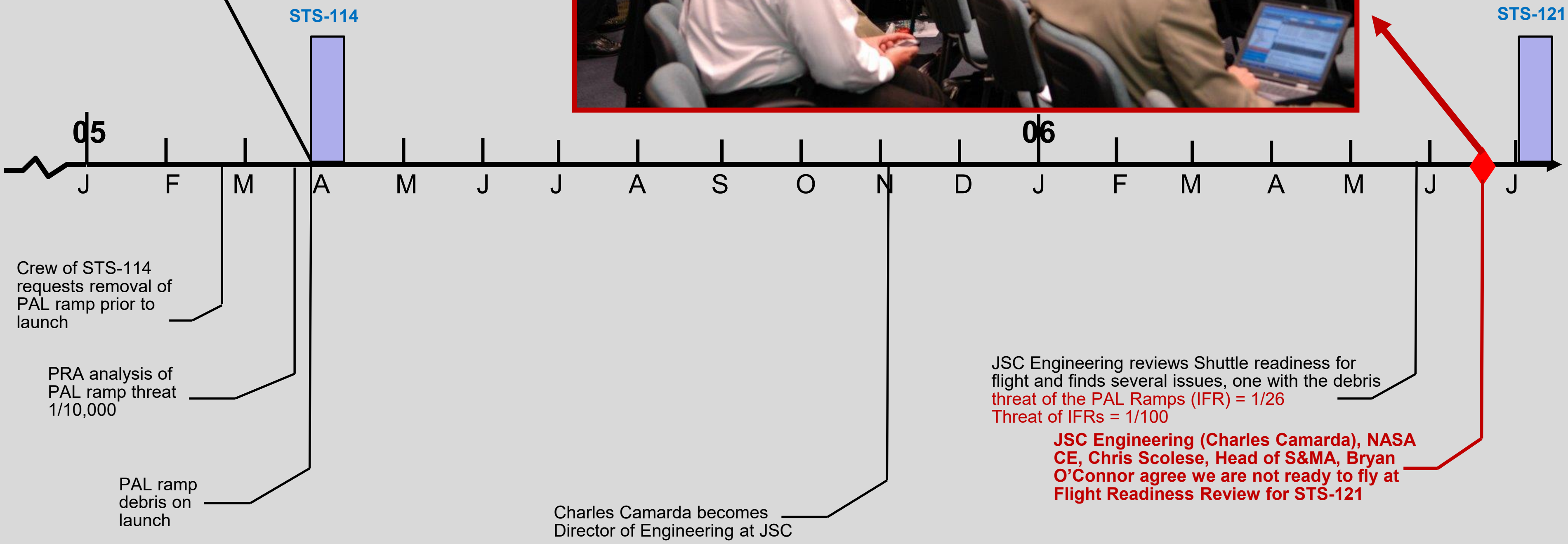
PAL ramp debris on launch
Charles Camarda becomes Director of Engineering at JSC
JSC Engineering reviews Shuttle readiness for flight and finds several issues, one with the debris threat of the Ice Frost Ramps (IFR) = 1/100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PRA analysis of PAL ramp threat 1/10,000
PAL ramp debris on launch
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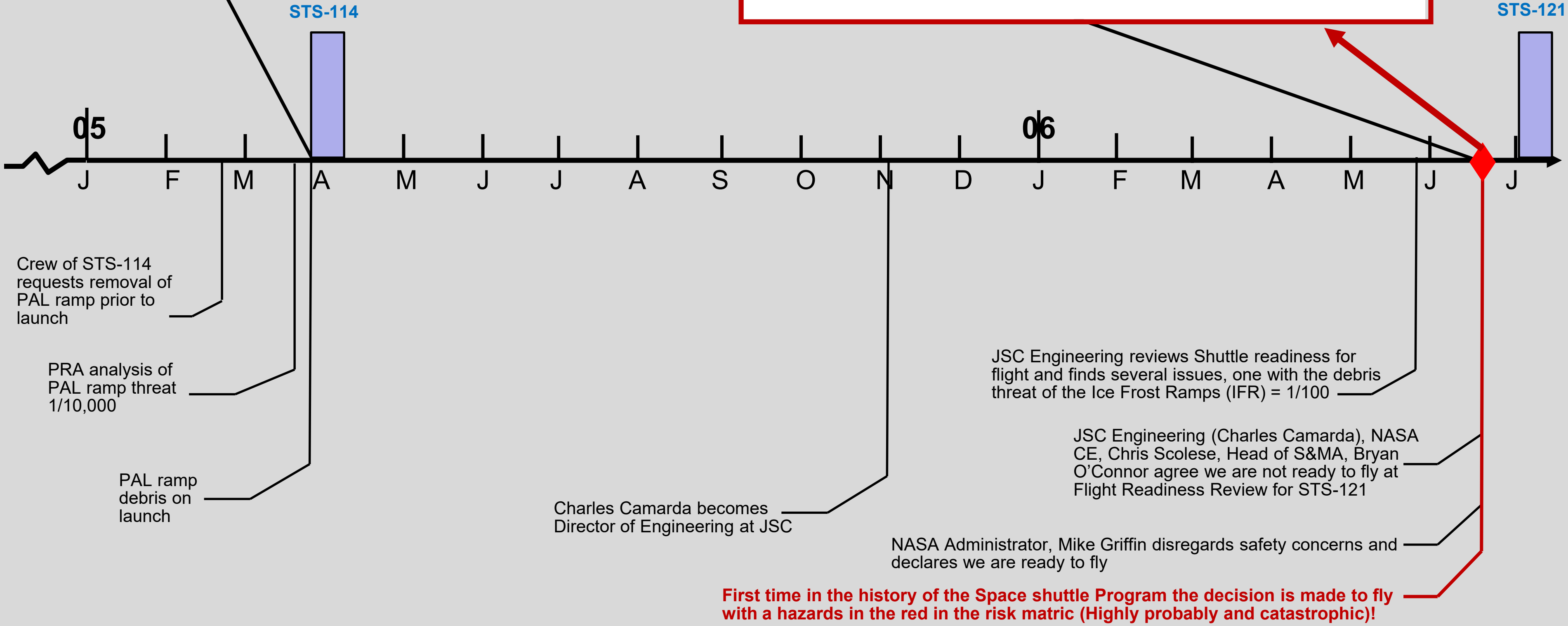
JSC Engineering reviews Shuttle readiness for flight and finds several issues, one with the debris
threat of the PAL Ramps (IFR) = 1/26
Threat of IFRs = 1/100
JSC Engineering (Charles Camarda), NASA CE, Chris Scolese, Head of S&MA, Bryan O'Connor agree we are not ready to fly at Flight Readiness Review for STS-121

(HAZARD SEVERITY LEVEL AND LIKELIHOOD OF OCCURRENCE WITH CONTROLS IN PLACE)

LIKELIHOOD	MARGINAL	CRITICAL	CATASTROPHIC
PROBABLE			2
INFREQUENT	2		23
REMOTE	2	7	142
IMPROBABLE	15	24	400

SEVERITY



First Time in History a Space Shuttle was Flown with Items in the Red Region of the Risk Likelihood Matrix

(HAZARD SEVERITY LEVEL AND LIKELIHOOD OF OCCURRENCE WITH CONTROLS IN PLACE)

LIKELIHOOD	MARGINAL	CRITICAL	CATASTROPHIC
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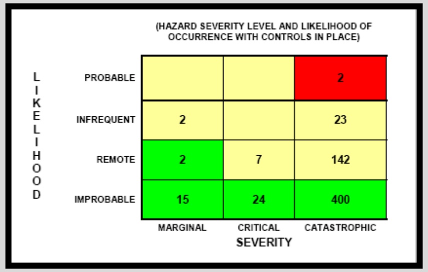
SEVERITY


(HAZARD SEVERITY LEVEL AND LIKELIHOOD OF OCCURRENCE WITH CONTROLS IN PLACE)
LIKELIHOOD
PROBABLE
INFREQUENT
REMOTE
IMPROBABLE
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2
23
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7
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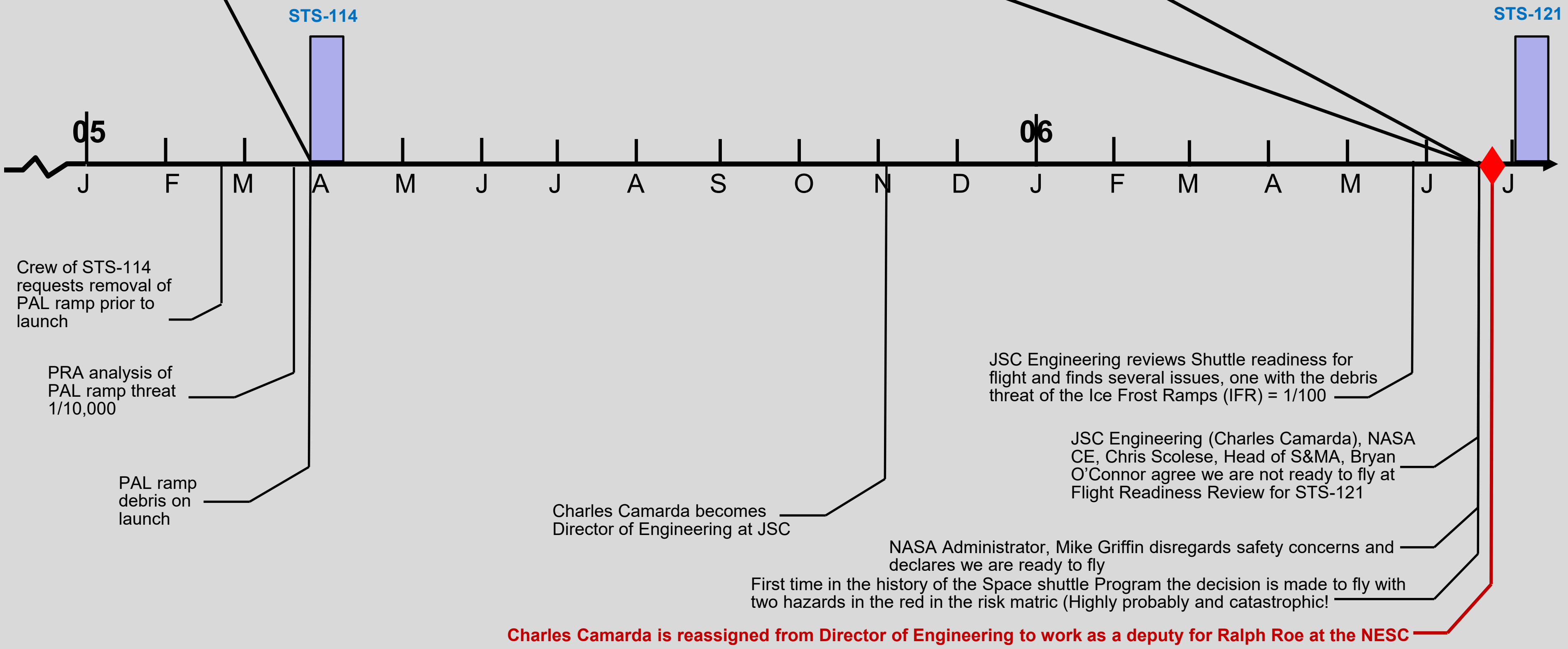
15
24
400
MARGINAL
CRITICAL
CATASTROPHIC
SEVERITY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JSC Engineering reviews Shuttle readiness for flight and finds several issues, one with the debris threat of the Ice Frost Ramps (IFR) = 1/100
JSC Engineering (Charles Camarda), NASA CE, Chris Scolese, Head of S&MA, Bryan O'Connor agree we are not ready to fly at Flight Readiness Review for STS-121
NASA Administrator, Mike Griffin disregards safety concerns and declares we are ready to fly
First time in the history of the Space shuttle Program the decision is made to fly with two hazards in the red in the risk matric (Highly probably and catastrophic!
Charles Camarda is reassigned from Director of Engineering to work as a deputy for Ralph Roe at the NESC

EA Dissenting Opinion on IDBR01and Ice Frost Ramp Flight Rationale

- EA does not concur with describing the debris risk from Ice Frost Ramps as Infrequent/Catastrophic. For the following reasons EA considers the risk Probable/Catastrophic
  - The risk assessment mass of 0.08lbm is several times larger than the orbiter tile impact and damage capability
  - Ground testing, ET-120 dissection, and stress analyses have all confirmed the constant, repeatable occurrence of the failure mechanism
  - Flight history confirms that releases occur every flight and includes masses up to and exceeding the risk assessment mass.
  - The release mechanism is not well understood which means time of release cannot be assured
  - There are no controls in place since the failure is a design flaw
  - Risk Assessment indices indicate a high probably (~ 1/100) of exceeding tile capability which depends on repair capability to not be catastrophic

Ice Frost Ramp (IFR) Foam Issue at Flight Readiness Review for STS-121

I have conducted a review for this mission and have determined that the technical products, processes, policies, and technical requirement variances for the Space Shuttle and International Space Station (for ISS missions) systems have been satisfactorily dispositioned, and that all associated residual technical risks have been appropriately characterized and accepted by Engineering and the Programs. ~~I concur with proceeding with this mission.~~ I REMAIN NO GO BASED UPON POTENTIAL LOSS OF VEHICLE HOWEVER FOR THIS MISSION I HAVE NO INTENTION TO APPEAL THE DECISION BASED UPON ISS CAPABILITY TO PROVIDE CSCS.

C. J. SCOLESE [signature] — 17 JUNE 2006

NASA CHIEF ENGINEER — DATE

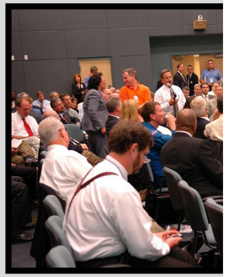
SSP Form 4042 (Rev Jun 06)

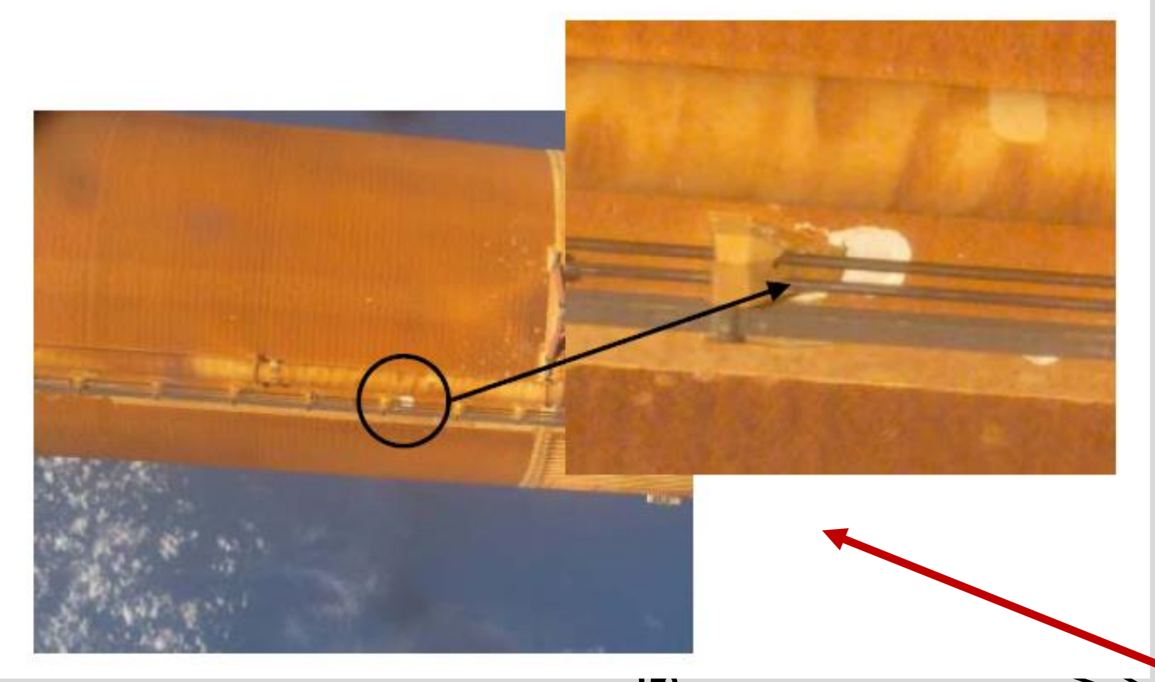
I have reviewed with the Space Shuttle Program and Center S&MA organizations the status of preparations for this mission including the Launch On Need (LON) rescue mission as briefed (if required, a LON FRR will be conducted and flight certification will be signed), and the readiness of the International Space Station for launch and on-orbit operations (for ISS missions), including the uncertified Contingency Shuttle Crew Support (CSCS) operation, as briefed. ~~I concur with proceeding with this mission.~~ I AM NO GO BASED ON LOSS OF VEHICLE RISK (ICE FROST RAMPS). BASED ON APPEAL TO ADMINISTRATOR I HAVE NO INTENTION TO APPEAL HIS RISK ACCEPTANCE AND CONCUR WITH PROCEEDING WITH MISSION

B. D. O'CONNOR [signature] — 17 JUNE 06

CHIEF OF SAFETY AND MISSION ASSURANCE — DATE

APPROVAL





STS-114

STS-121

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J F M A M J J A S O N D J F M A M J J

Crew of STS-114 requests removal of PAL ramp prior to launch

PRA analysis of PAL ramp threat 1/10,000

PAL ramp debris on launch

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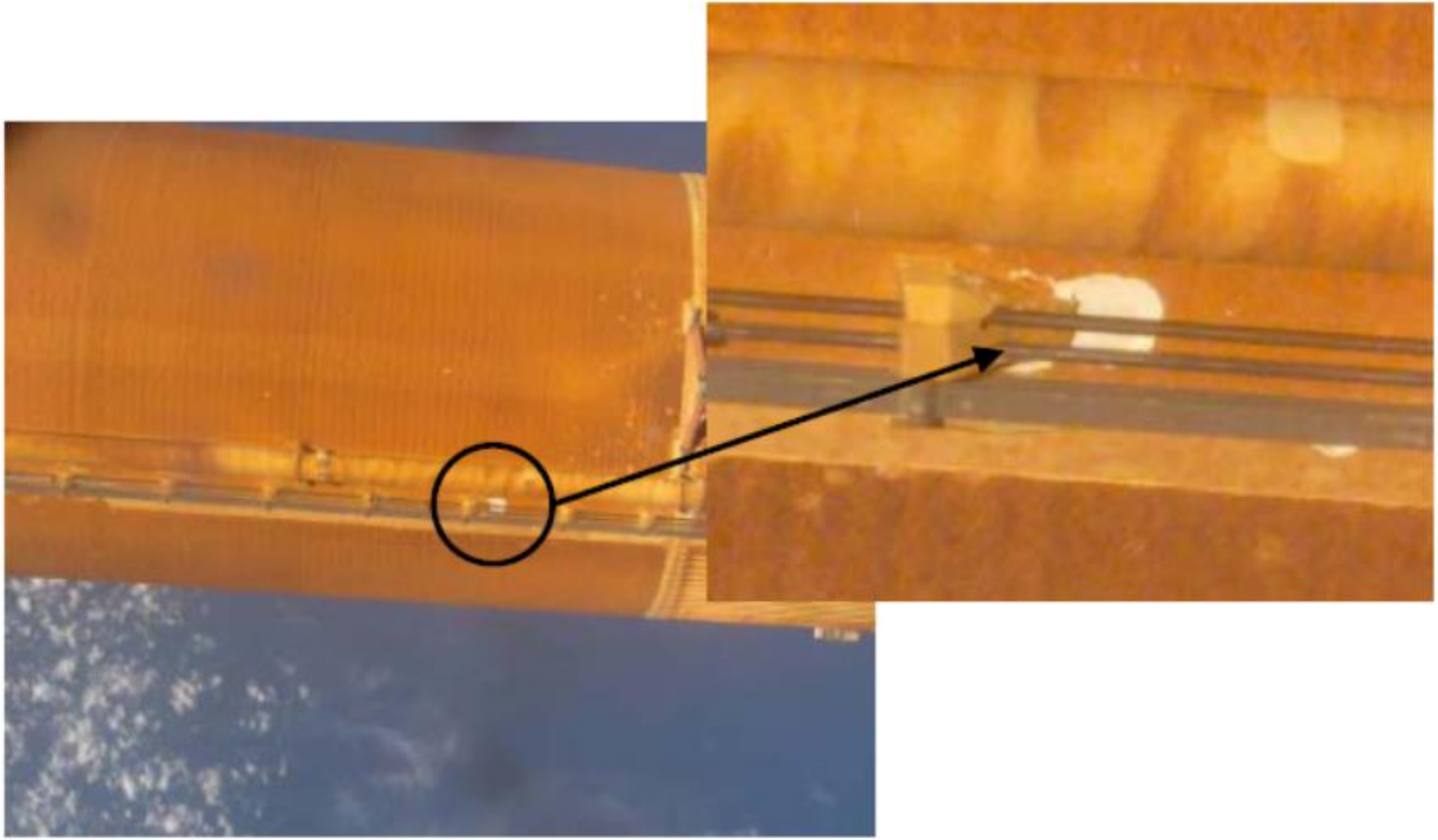
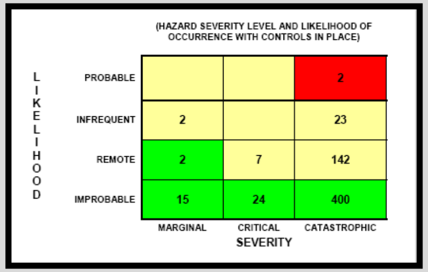
NASA Administrator, Mike Griffin disregards safety concerns and declares we are ready to fly

First time in the history of the Space shuttle Program the decision is made to fly with two hazards in the red in the risk matric (Highly probably and catastrophic!

Charles Camarda is reassigned from Director of Engineering to work as a deputy for Ralph Roe at the NESC

IFR debris on launch of STS-121 barely misses port wing leading edge





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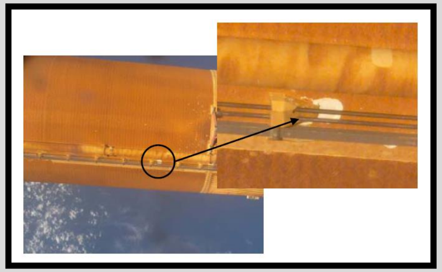
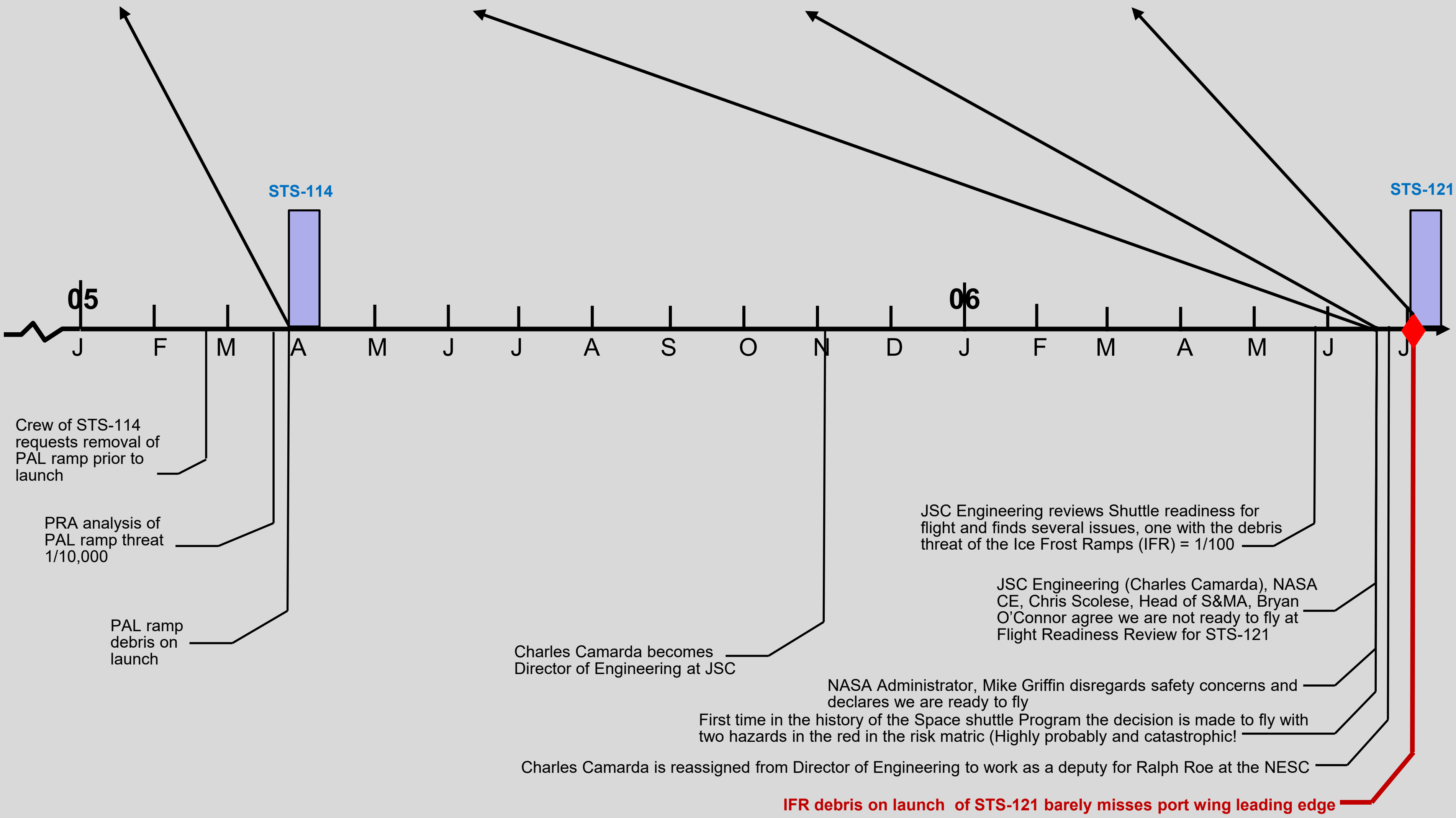
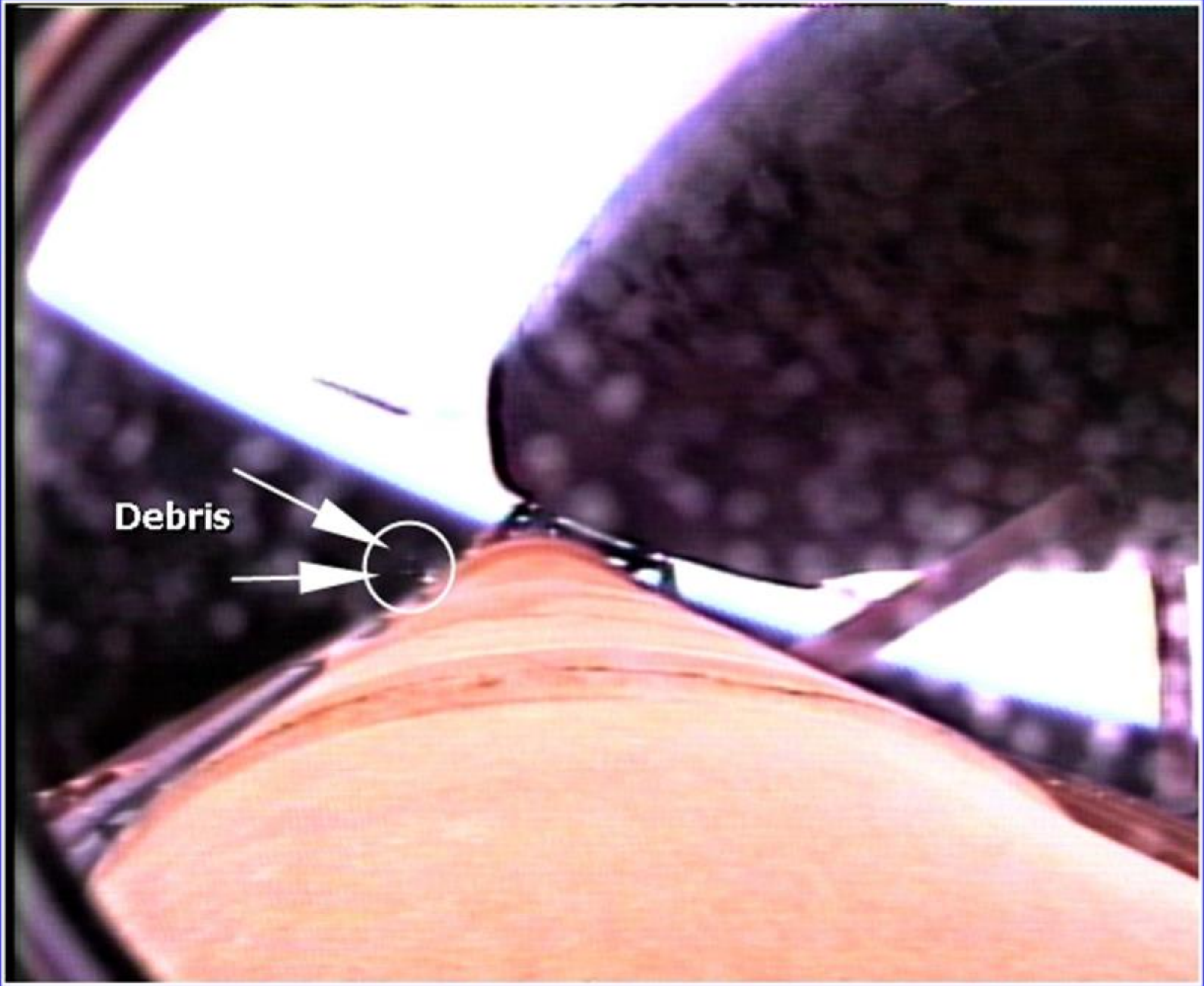




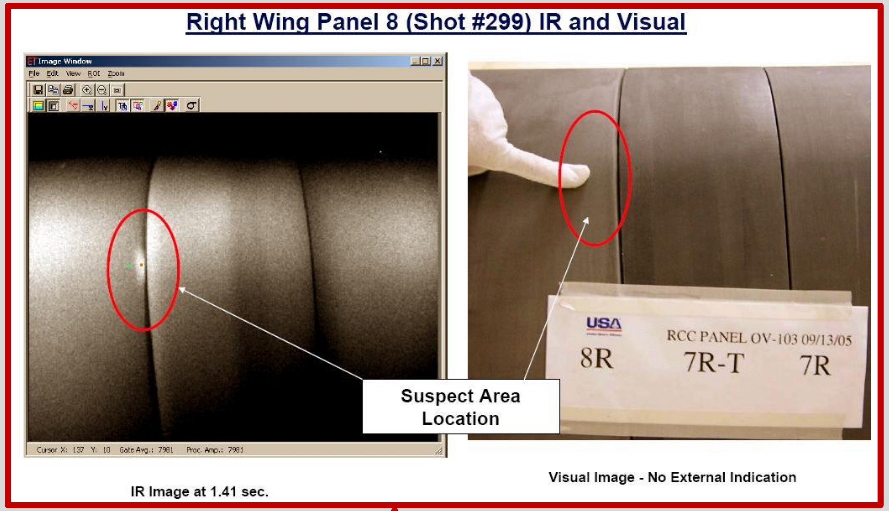
STS-121 MET 285.0 seconds Camera TIR110

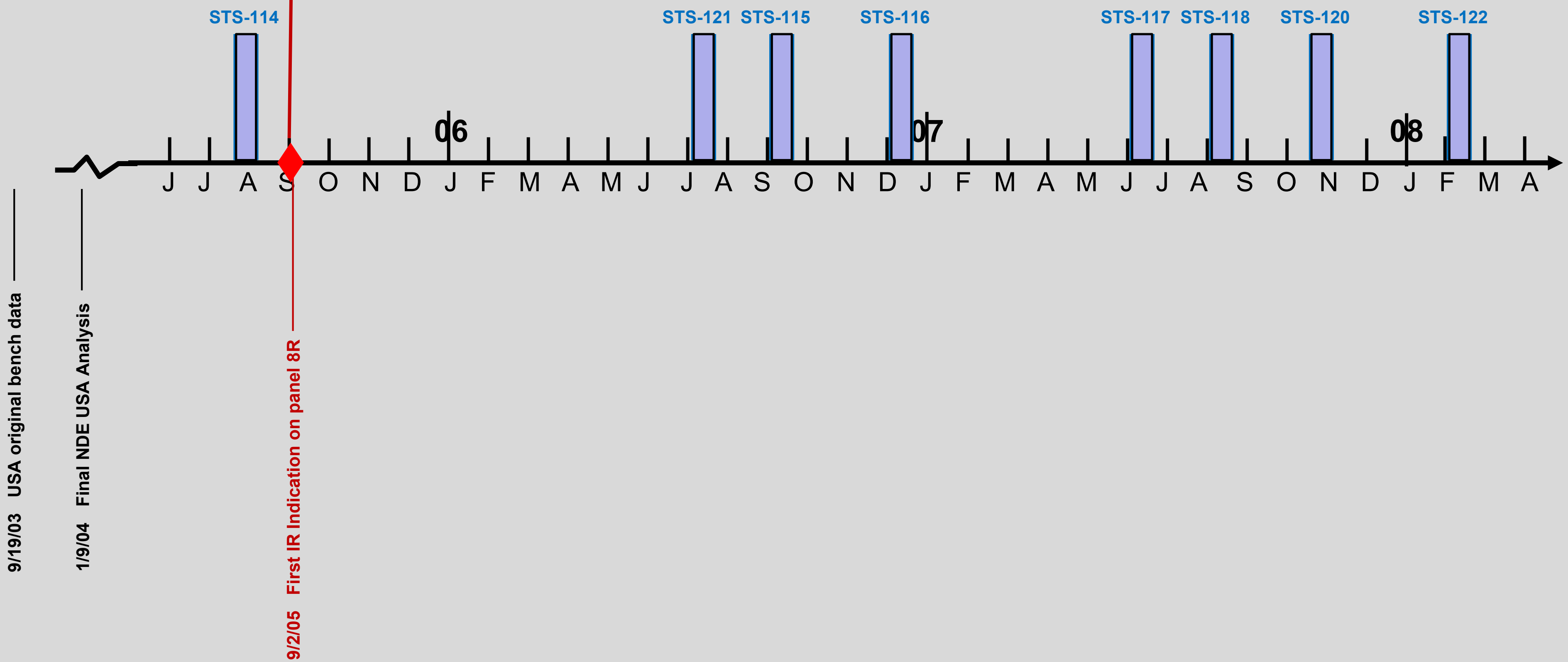


Marshall Space Flight Center
Engineering Photographic Analysis

Post STS-114

RCC Panel 8R Anomaly


Right Wing Panel 8 (Shot #299) IR and Visual
Image Window
Suspect Area Location
USA
RCC PANEL OV-103 09/13/05
8R
7R-T
7R
IR Image at 1.41 sec.
Visual Image - No External Indication


STS-114
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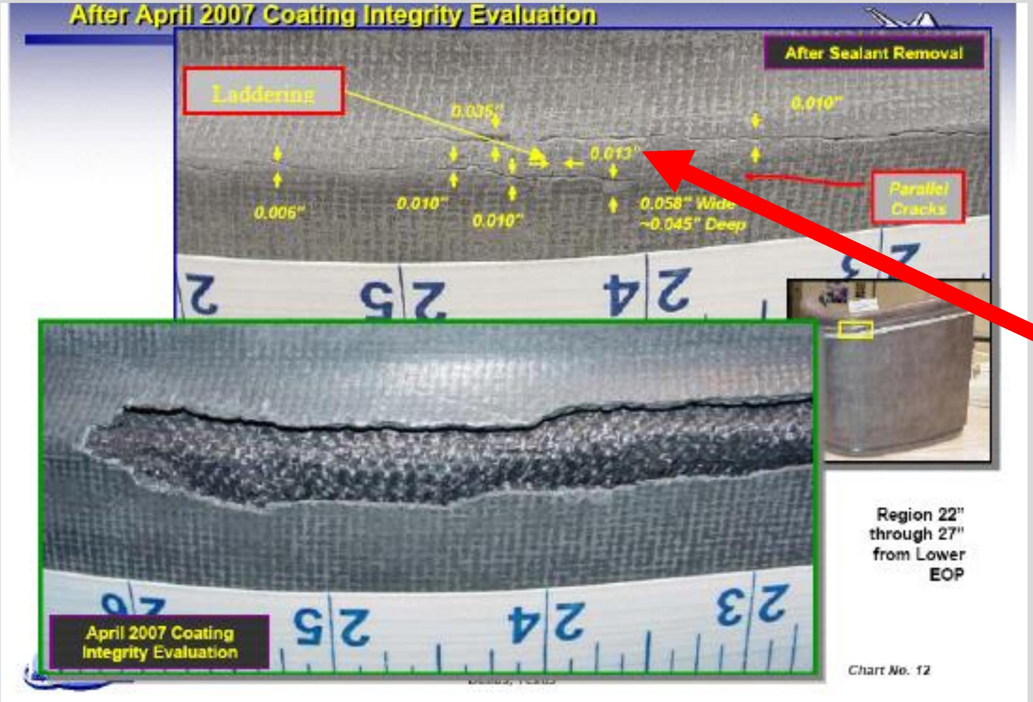
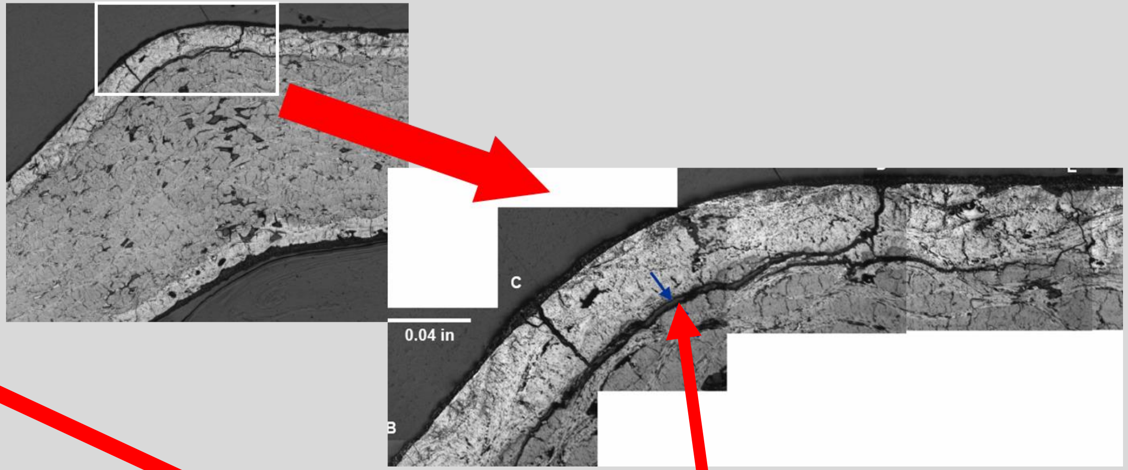
J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A
9/19/03 USA original bench data
1/9/04 Final NDE USA Analysis
9/2/05 First IR Indication on panel 8R

Joggle/Step Gap Region

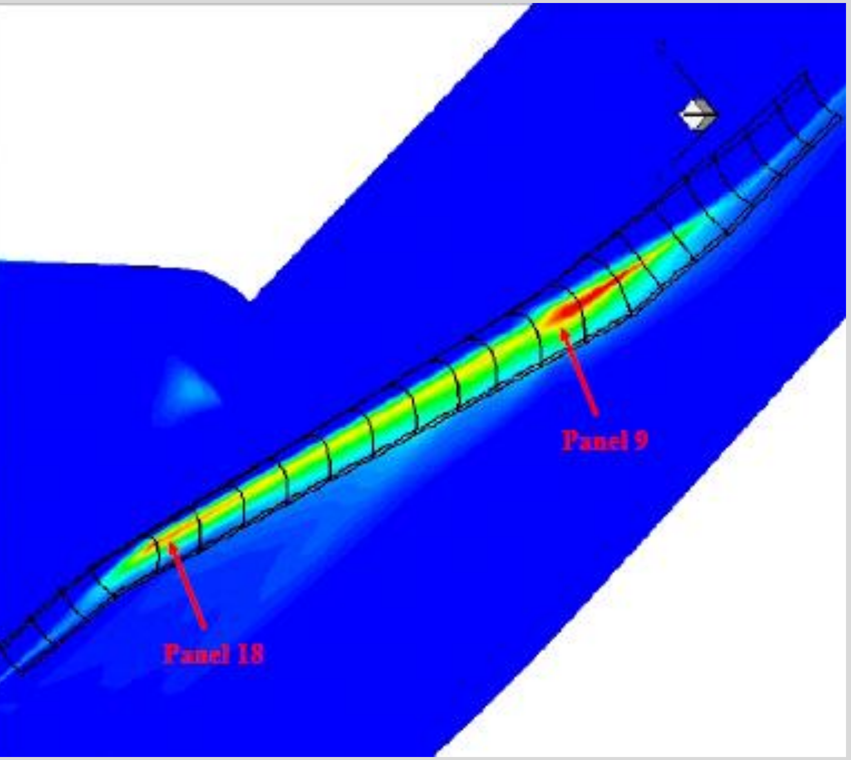
Potential “Zippering” of SiC Chips



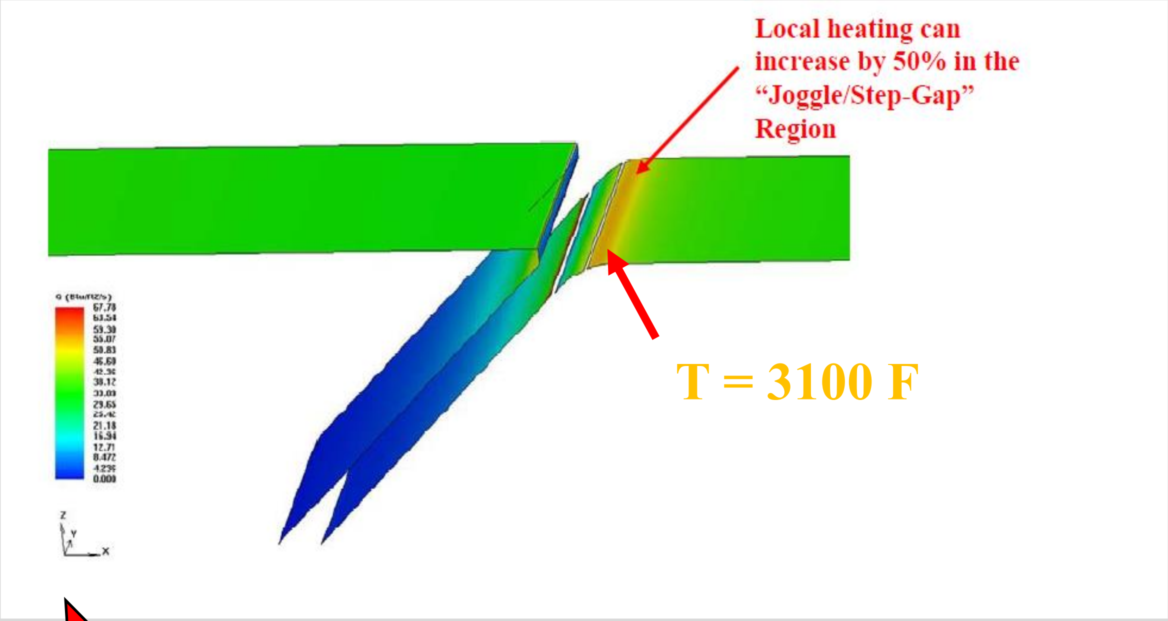


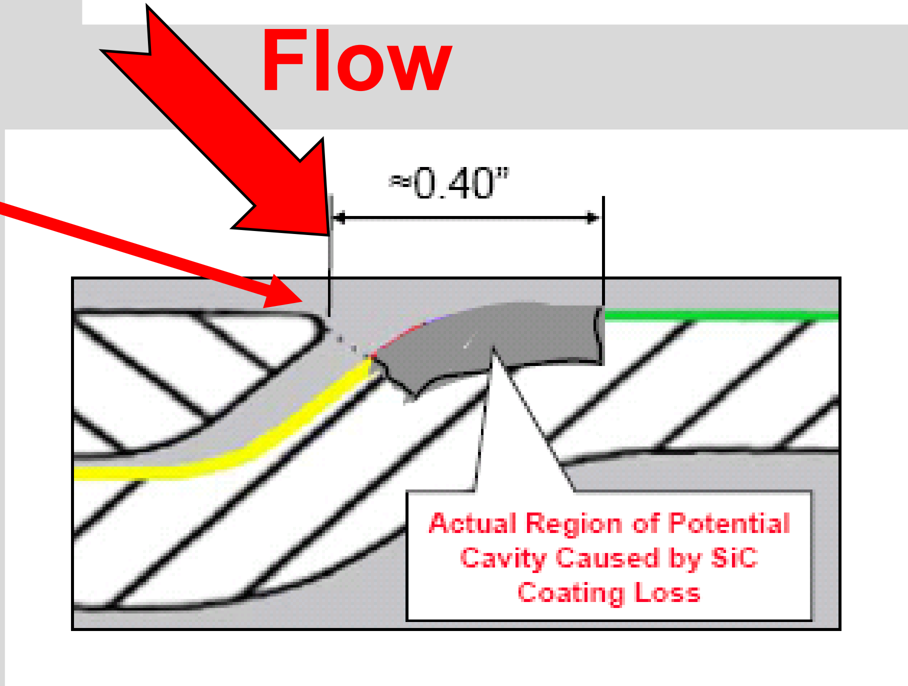
Large chordwise cracks and transverse “laddering” cracks can easily cause a “zippering” effect of delaminated SiC coating pieces

Aerothermal Heating Along Wing Leading Edge



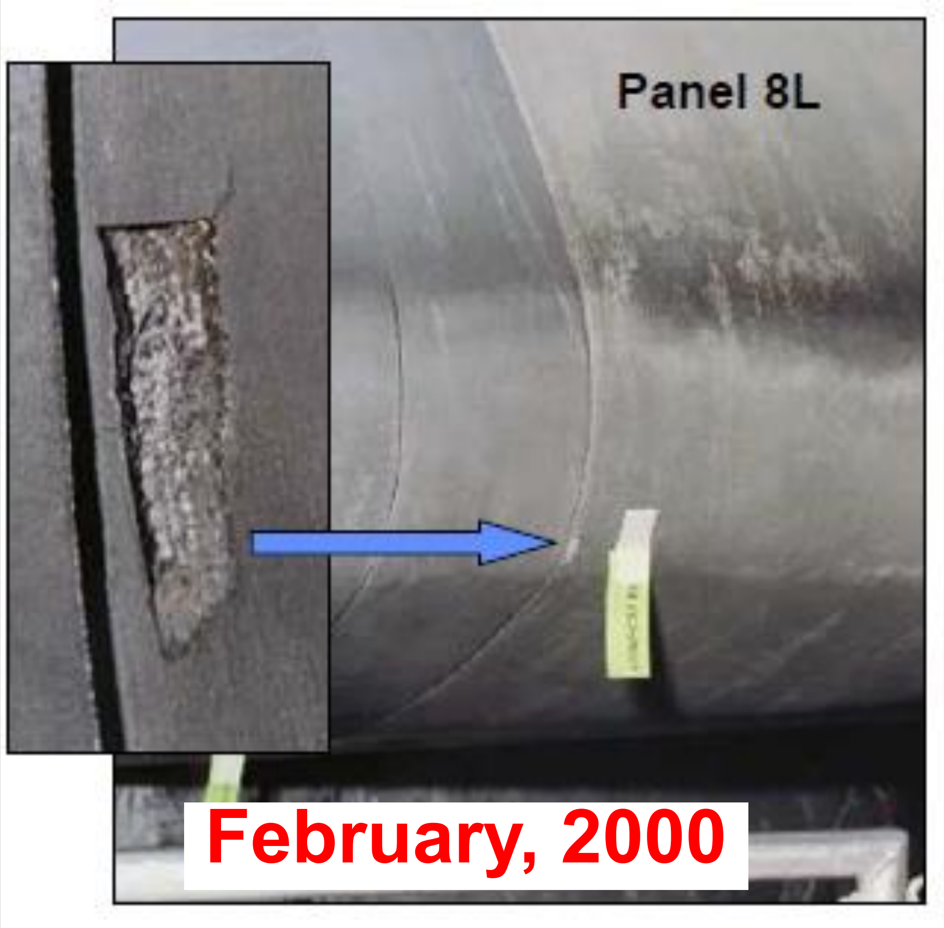

Panel 8R



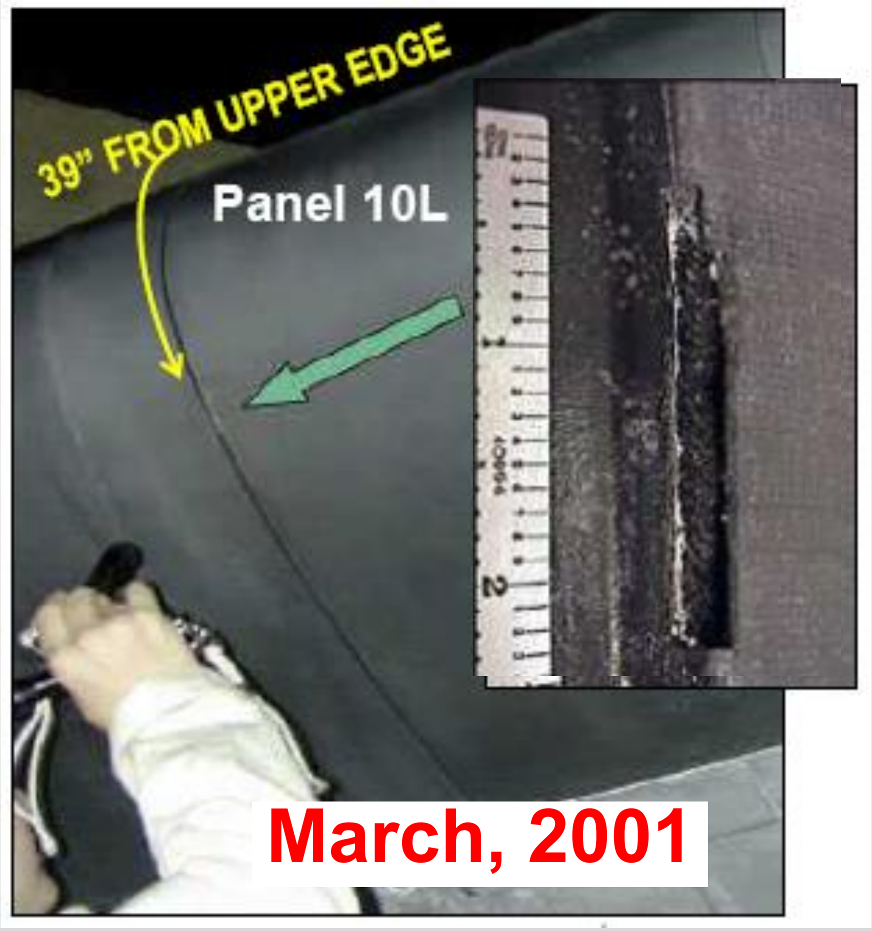


Prior Indications of Slip-Side Coating Loss

Yet LESS-PRT Claimed this was not a systemic problem

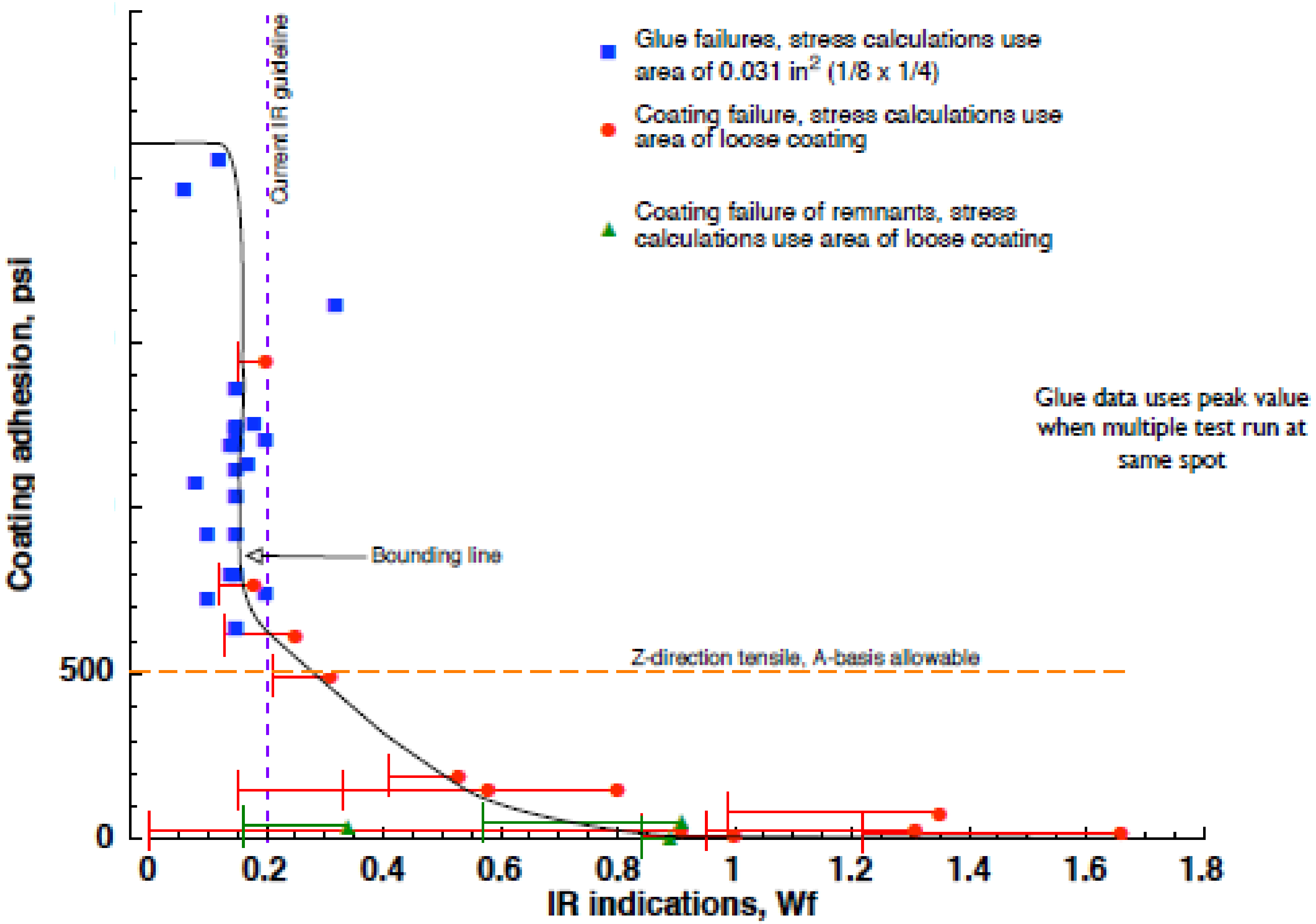


Discrepant Panel determined to exceed repair capability; scrapped and replaced



Discrepant Panel was repaired and used for one flight, after which it was taken out of service.

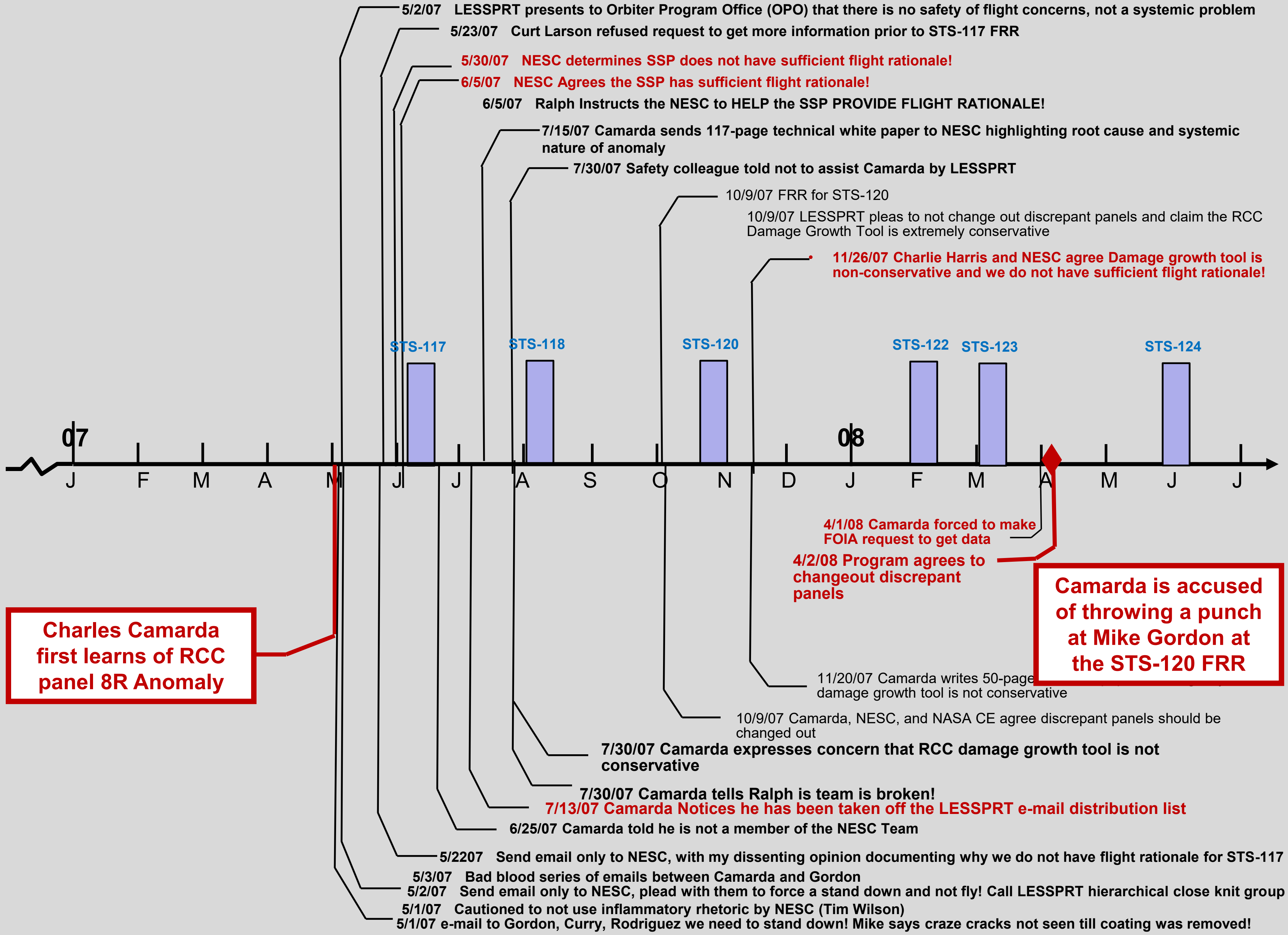
Summary Joggle Data Plot



Panel Histories Prior to Damage Incident or STS-117 Launch

Panel Number	No. of Flights	No. of Repairs	No. of Refurbishments	Flights since last Refurbishment
Historic Data for Coating Damaged Panels				
8L, OV-103	27	3	2	2
10L, OV-103	29	1	2	4
NC, OV-105	19	0	1	0
8R, OV-103	31	2	3	1
STS-117, OV-104				
1L, 2L, 3L, 4L, 5L	27	0	0	NA
6L	27	1	1	1
7L	27	0	1	7
8L	1	0	0	NA
9L	27	0	1	7
10L	27	1	1	7
11L, 12L	27	0	1	7
13L	1	0	0	NA
*14L	18	0	1	7
15L	27	0	1	7
*16L, *17L	18	0	1	7
18L	18	0	0	NA
19L, 20L, 21L, 22L	27	0	0	NA
1R, 2R, 3R, 4R, 5R	27	0	0	NA
6R, 7R, 8R, 9R	27	0	1	7
*10R	16	0	1	7
11R, 12R, 13R, 14R	27	0	1	7
15R	18	0	1	7
16R	1	0	0	NA
*17R	18	0	1	7
18R	18	1	0	NA
19R, 20R, 21R, 22R	27	0	0	NA

Panels with Thermographic NDE indication marked *


5/2/07 LESSPRT presents to Orbiter Program Office (OPO) that there is no safety of flight concerns, not a systemic problem
5/23/07 Curt Larson refused request to get more information prior to STS-117 FRR
5/30/07 NESC determines SSP does not have sufficient flight rationale!
6/5/07 NESC Agrees the SSP has sufficient flight rationale!
6/5/07 Ralph Instructs the NESC to HELP the SSP PROVIDE FLIGHT RATIONALE!
7/15/07 Camarda sends 117-page technical white paper to NESC highlighting root cause and systemic nature of anomaly
7/30/07 Safety colleague told not to assist Camarda by LESSPRT
10/9/07 FRR for STS-120
10/9/07 LESSPRT pleas to not change out discrepant panels and claim the RCC Damage Growth Tool is extremely conservative
11/26/07 Charlie Harris and NESC agree Damage growth tool is non-conservative and we do not have sufficient flight rationale!
STS-117
STS-118
STS-120
STS-122
STS-123
STS-124
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J
4/1/08 Camarda forced to make FOIA request to get data
4/2/08 Program agrees to changeout discrepant panels
Camarda is accused of throwing a punch at Mike Gordon at the STS-120 FRR
Charles Camarda first learns of RCC panel 8R Anomaly
11/20/07 Camarda writes 50-page
damage growth tool is not conservative
10/9/07 Camarda, NESC, and NASA CE agree discrepant panels should be changed out
7/30/07 Camarda expresses concern that RCC damage growth tool is not conservative
7/30/07 Camarda tells Ralph is team is broken!
7/13/07 Camarda Notices he has been taken off the LESSPRT e-mail distribution list
6/25/07 Camarda told he is not a member of the NESC Team
5/2207 Send email only to NESC, with my dissenting opinion documenting why we do not have flight rationale for STS-117
5/3/07 Bad blood series of emails between Camarda and Gordon
5/2/07 Send email only to NESC, plead with them to force a stand down and not fly! Call LESSPRT hierarchical close knit group
5/1/07 Cautioned to not use inflammatory rhetoric by NESC (Tim Wilson)
5/1/07 e-mail to Gordon, Curry, Rodriguez we need to stand down! Mike says craze cracks not seen till coating was removed!

Summary of 8R Anomaly

- We have experienced a systemic problem with Shuttle RCC panels:
  - Problem first experienced December 1999
  - A second SiC coating chip was lost post March 2001
  - Panel 8R experienced severe coating degradation post STS-114, in August 2005
  - Camarda raises concerns in May 2007
  - SSP and NESC agrees with Camarda's recommendation and begins panel change-outs in April 2008
- It took eight years to identify and replace RCC panels which had systemic problems (Criticality 1 hardware)
- We flew 8 flights with faulty/discrepant RCC Panels!

Transforming NASA

Proposal to NASA HQ in 2019

Building a World-Class Team and Strategic Partnerships (2014 - 2019)

The Founding Team (SAA Partners)

Education & Learning Science ✚ **Workforce Development** ✚ **Computer Science** ✚ **Complex Engineering Problem Solving** ✚ **Innovation**

Mike Richey
Boeing
Chief Learning Officer

Charlie Camarda
NASA
Engineer, Innovator

Additional Partners

- Microsoft
- Siemens
- Etc.

The Current Partners

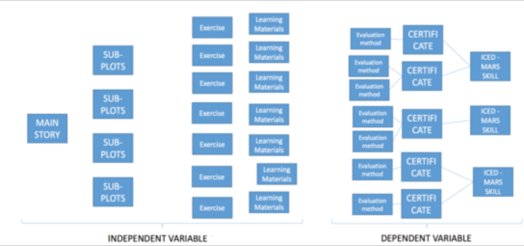
Frank Cicio
iQ4, CEO

Peter Moralis
CIEE, CIO

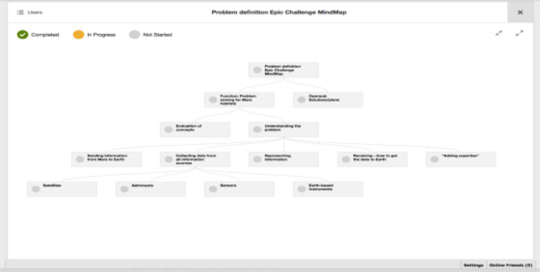
Janne Hietala
VALAMIS, CCO

Collaborative Platform for Learning (Valamis (Arcusys Inc.))

24/7 mobile links: connect learners to lessons, content, peers, mentors and experts

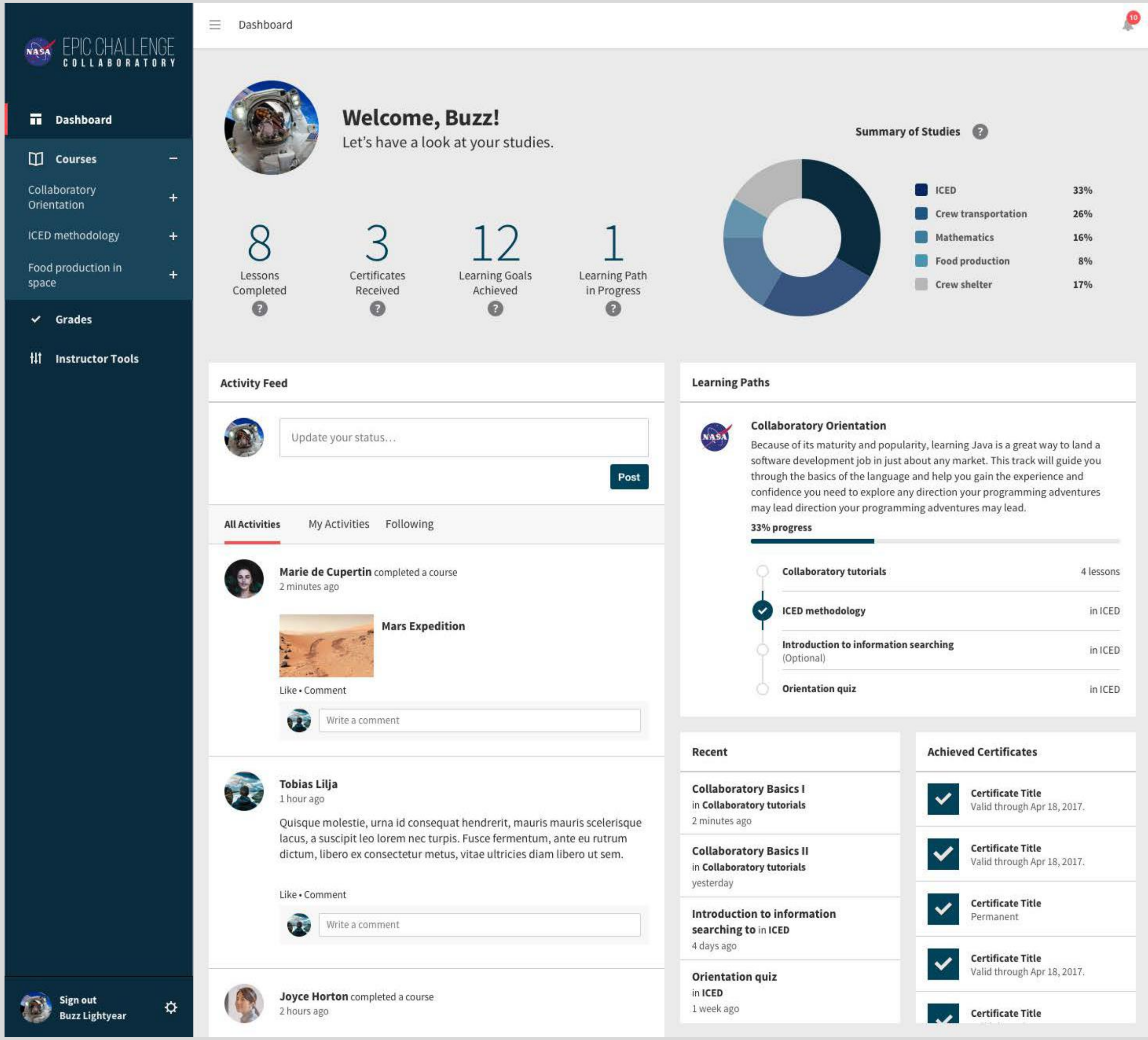


Phenomenon-Based Learning



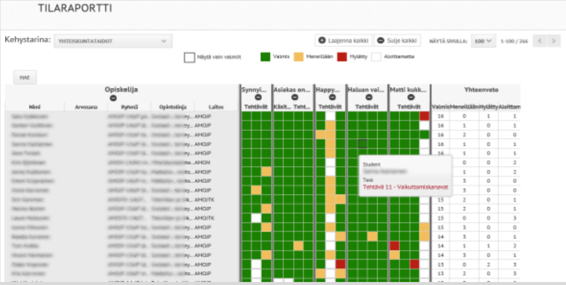
Concept Map*: links prior knowledge with current and projected future learning to produce "meaningful learning"

*Prof. Joe Novak, Cornell

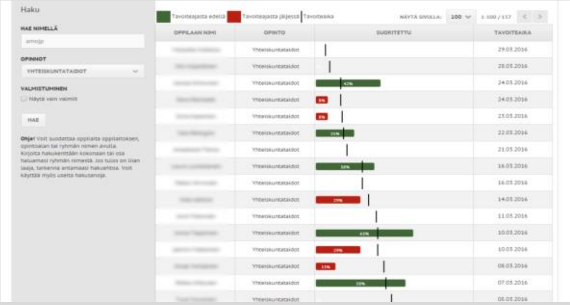


Dashboard/Home Page

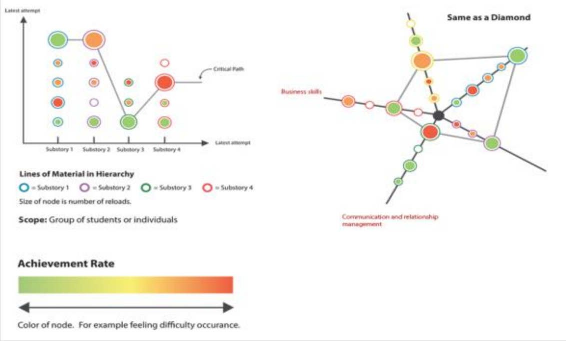
Learning Analytics



Group analysis – identifying patterns



Group analysis – progress mapping



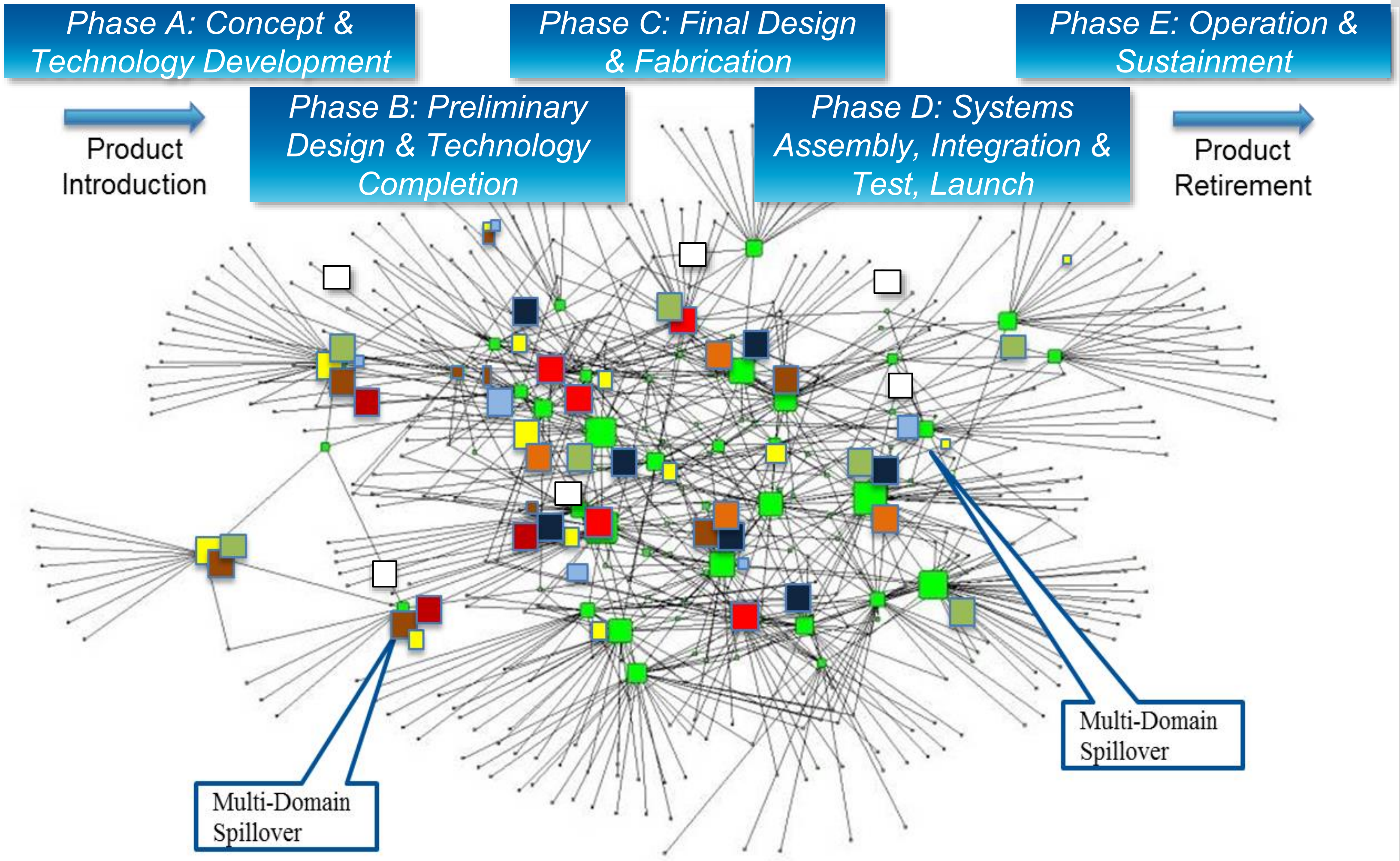
Individual analysis – strategic skills

Boeing AerosPACE Program

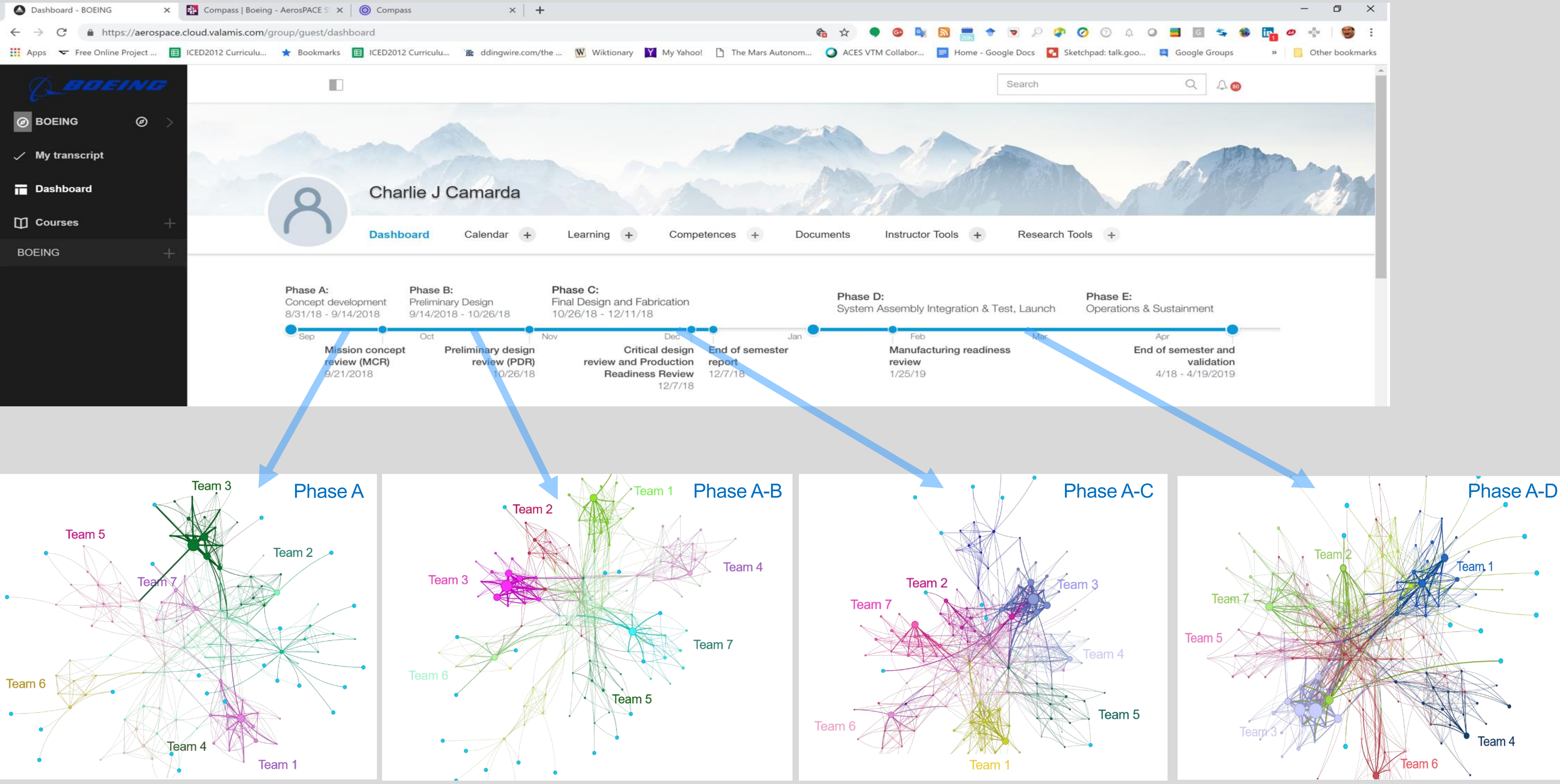
(Problem-/Project- Based Learning)

- Aerodynamics
- System Engineering
- Structures, Design & Analysis
- Manufacturing Engineers
- Tool Engineering
- Electrical Engineering
- Industrial Engineering
- Program Management
- Enterprise Management

AerosPACE: A self-organizing network where agents understand and regulate their own learning through problem based, situated learning

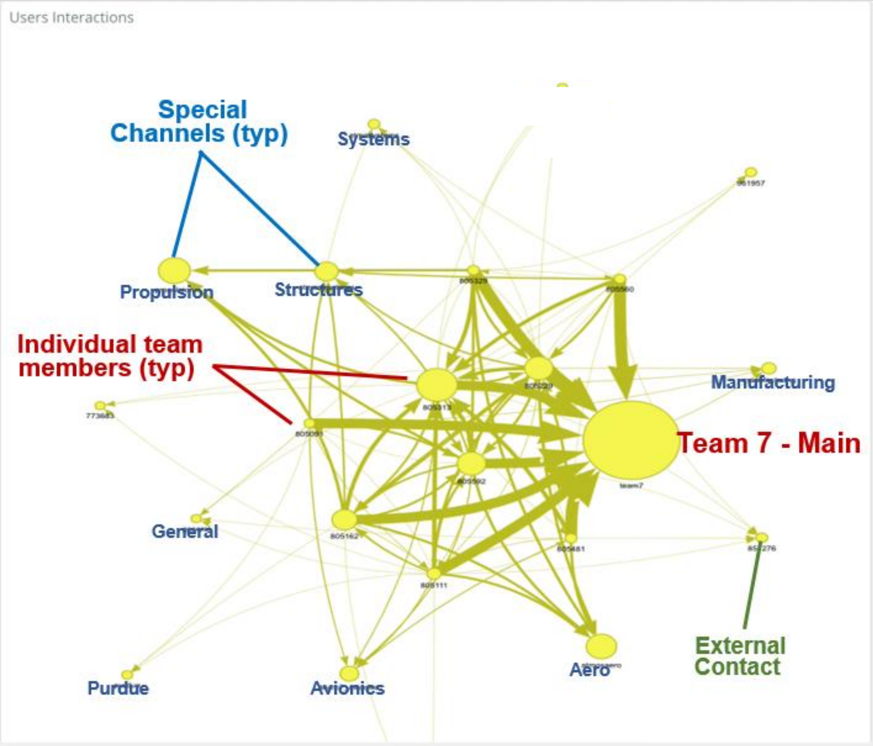


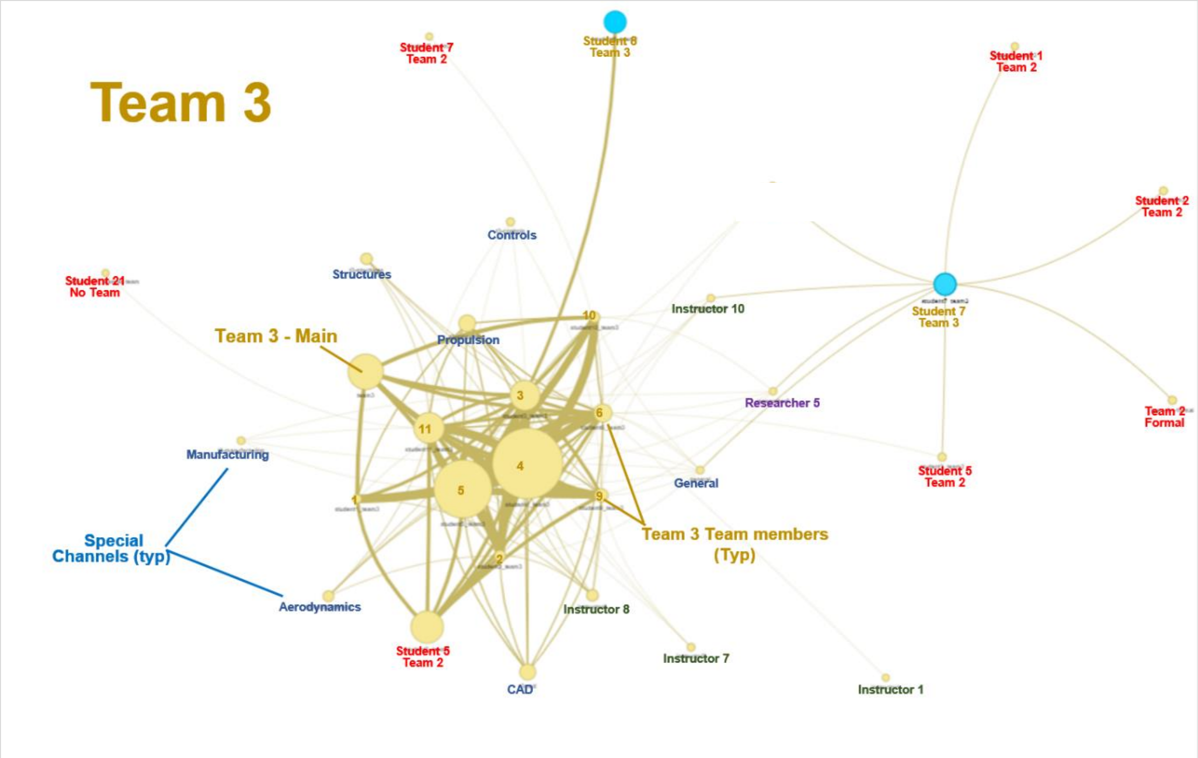
Slack Channel Formation as a Function of Program Phase



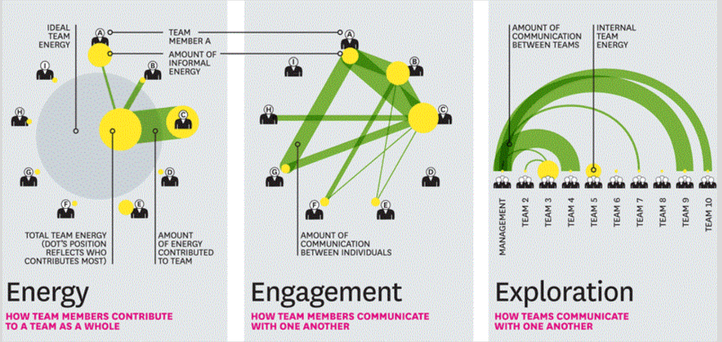
Boeing AerosPACE Comparison of Communication

Teams 7 and 3

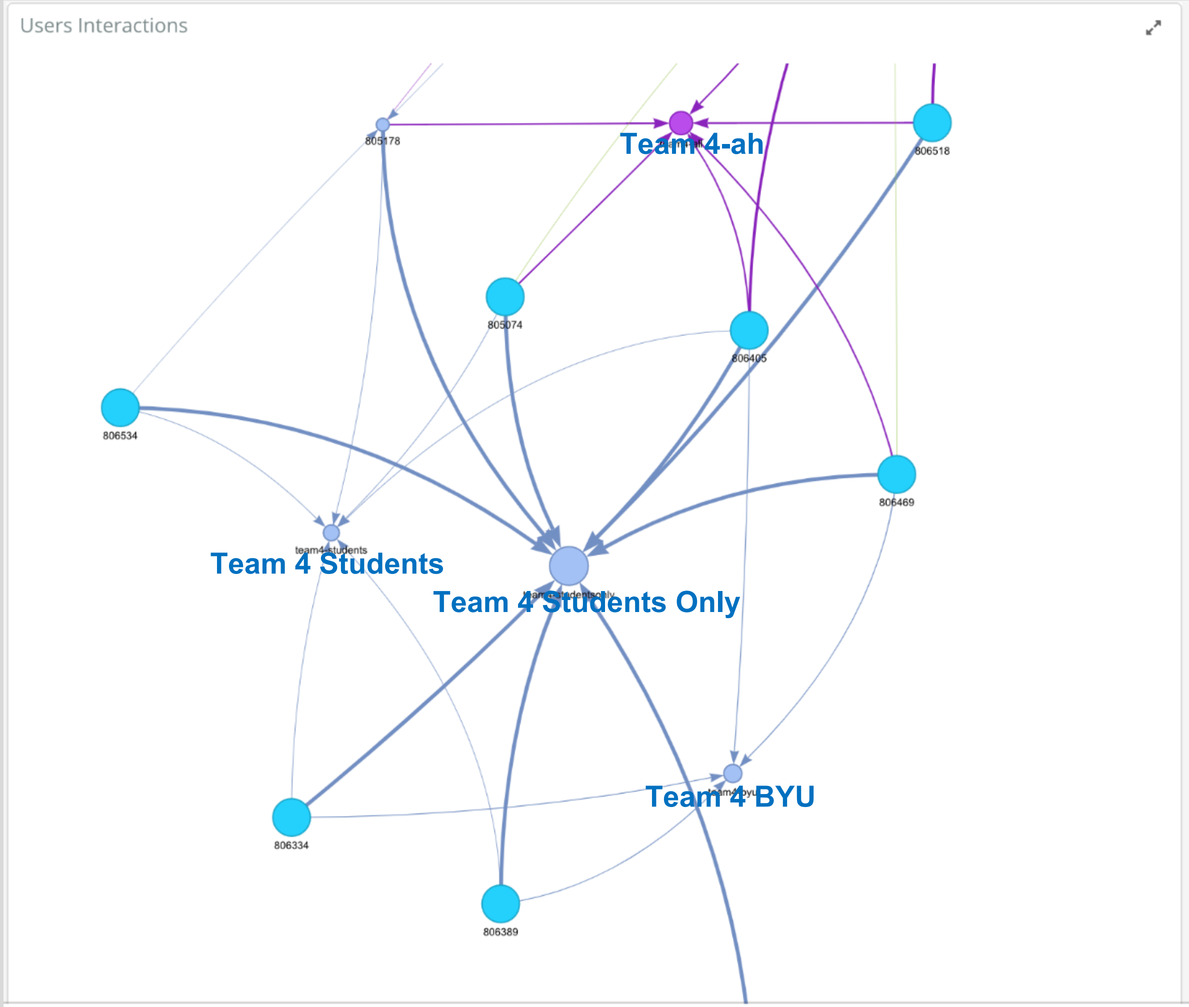




- **Energy** – is high on both teams
- **Engagement** – is more pronounced on Team 3 with a larger number of direct messages between team members
- **Exploration** – is slightly higher on Team 3



Phase A - Team 4 has formed specialized channels

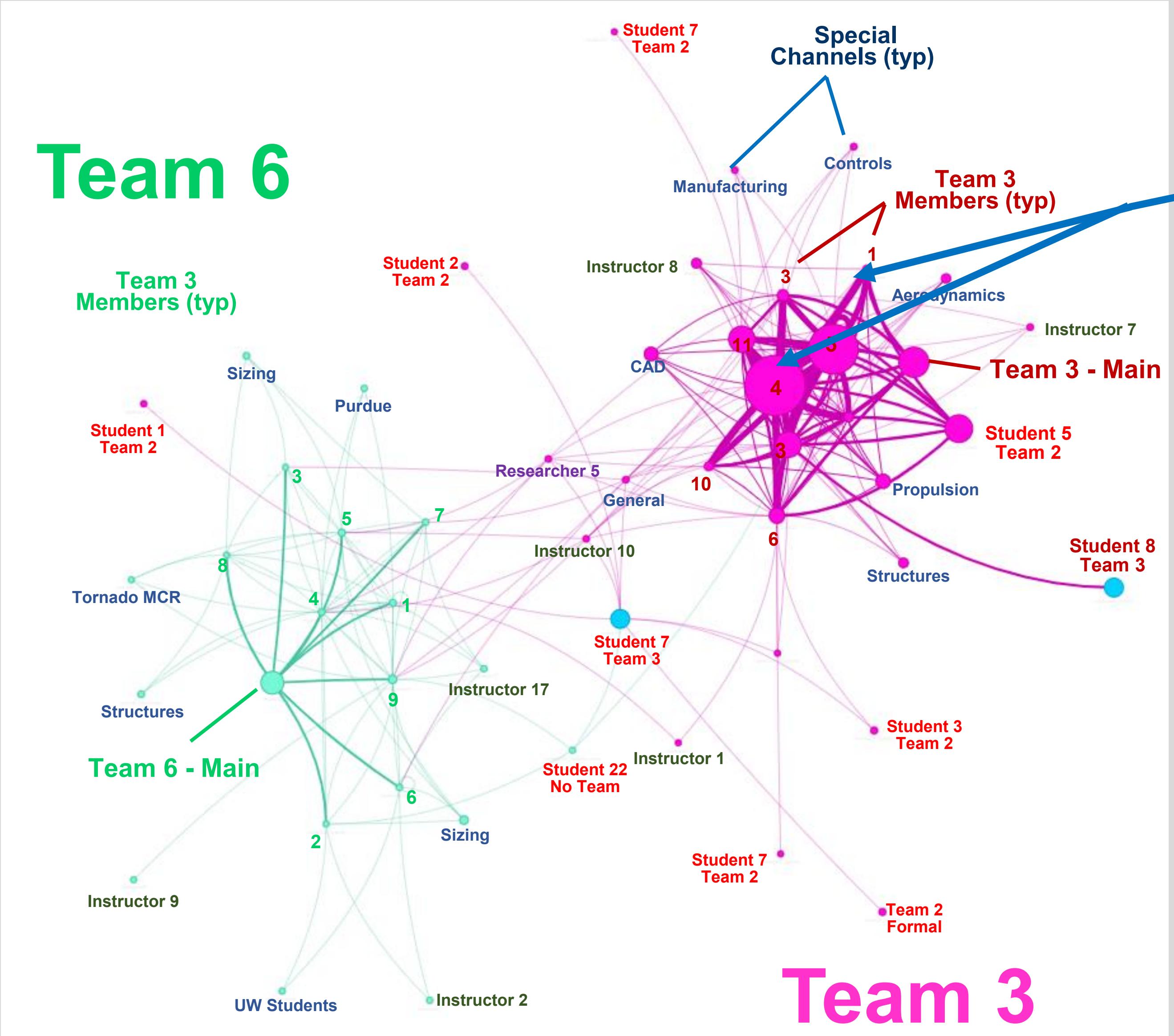


Team 4 - Chose to create a private, “student’s only” channel

- Would be interesting to measure the level of psychological safety of this team

Boeing AerosPACE Comparison of Teams 3 and 6

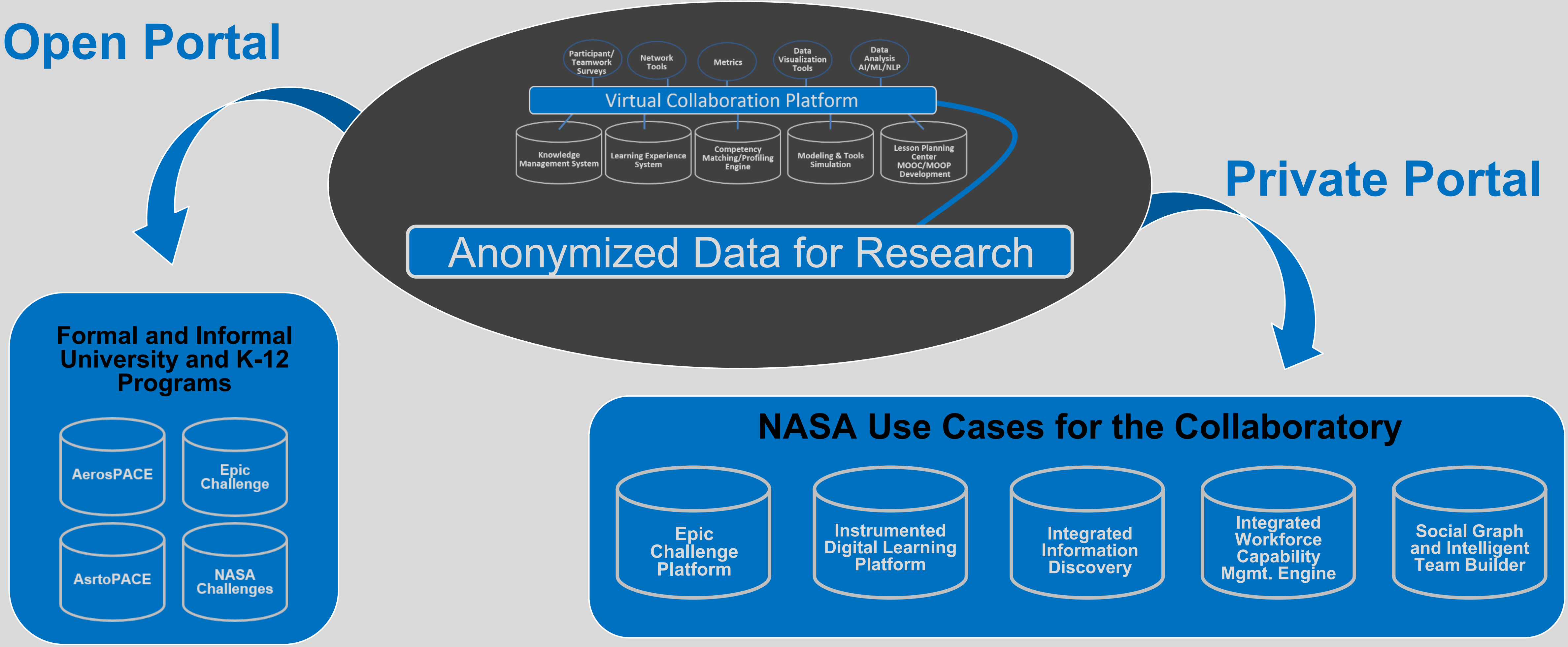
Social Communication Frequency (Aug. 31, 2018 to March 17, 2019)



Line thickness and size of symbol is related to activity

Team 3 has very high engagement and energy compared to Team 6

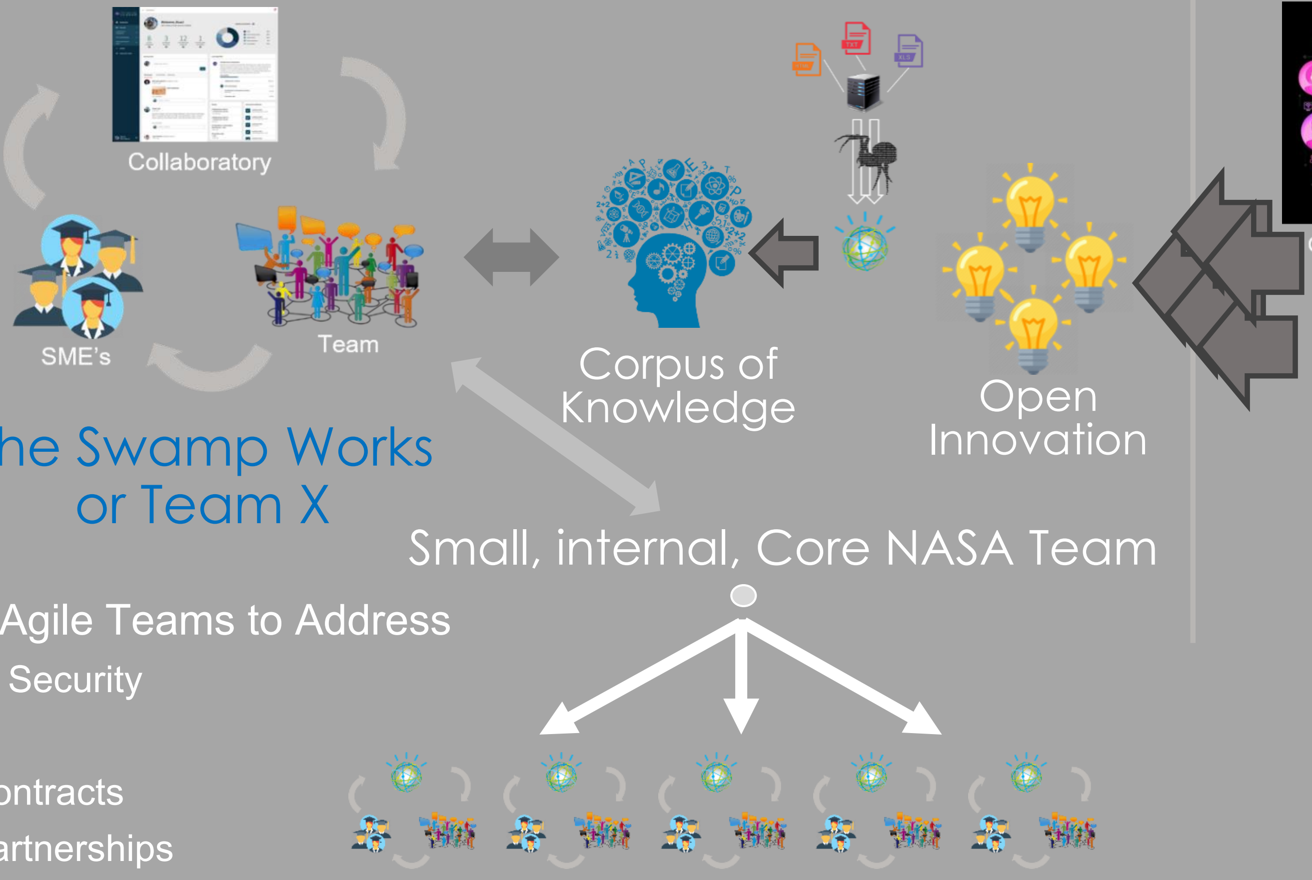
Collaboratory



A Proposed Global Grand Challenge

Measuring the Performance of Geographically Dispersed Teams Solving Complex, System-of-Systems Problems

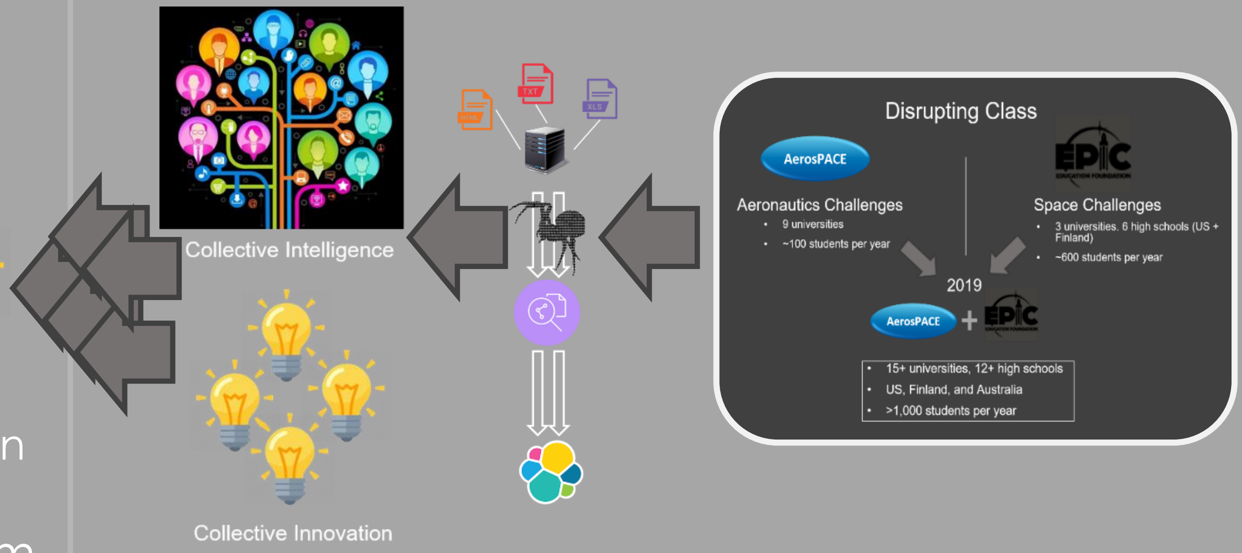
Internal, Protected Portal ~ 20 Participants



Small, Agile Teams to Address

- IT Security
- IP
- Contracts
- Partnerships
- Education
- Etc.

External, Open Portal > 1,000 participants



Disruptive, Open Innovation

Large, Open Platform to Research

- Scalability
- User experience
- Team behavior
- Collective creativity and innovation
- Program/project performance
- Data analytics, AI/ML, effectiveness
- Social & learning physics

Acknowledgments

I would like to thank the army of research engineers and scientists throughout the three NASA Research Centers, Langley, Ames, and Glenn for their dedication to excellence and understanding the complex unknowns related to spaceflight, for determining the cause of the Columbia accident, for their work during our return-to-flight in 2005, and in ensuring we continued to fly space shuttle safely up until its retirement in 2011.

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Sandra Walker
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Scott Berry
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Wallace Vaughan
Erik Maderas
Bill Winfree
Ed Fasanella
Delma Freeman
Erik Weiser
Mia Siochi
Marshall Rouse
Dawn Jegley
Norm Knight
Dave Moore
K. Song
Ronald Kraeger
Mark Cagel
Genevieve Dixon
Ray Milneck
James Florance
Karen Jackson
Karen Lyles
Terry St. Clare
Kevin Rivers
Steve Altar
Bill Woods
Chris Glass
Bob Novac
Frank Novak
Damodar Ambur
Charlie Miller
Mark Hilburger

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Joe Lavelle
George Raiche
John Balboni
James Reuter
Tina Panontin
Stuart Rogers
Jay Grinstead
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Angel Otero
Fred Oswald
Fred Morales
Tim Krantz
Bob Handschuh
Ken Street
Jim Zecrichek
James Frazier
Fran Hurwitz
Beth Opila

Do you think NASA is a Learning Organization?

Artemis I Heatshield Return from Lunar Flyby December 11, 2022


Questions?