Risk Tolerance and Safety Culture:

Minimizing the Risk of Catastrophe by Bringing the Lessons of Space Home

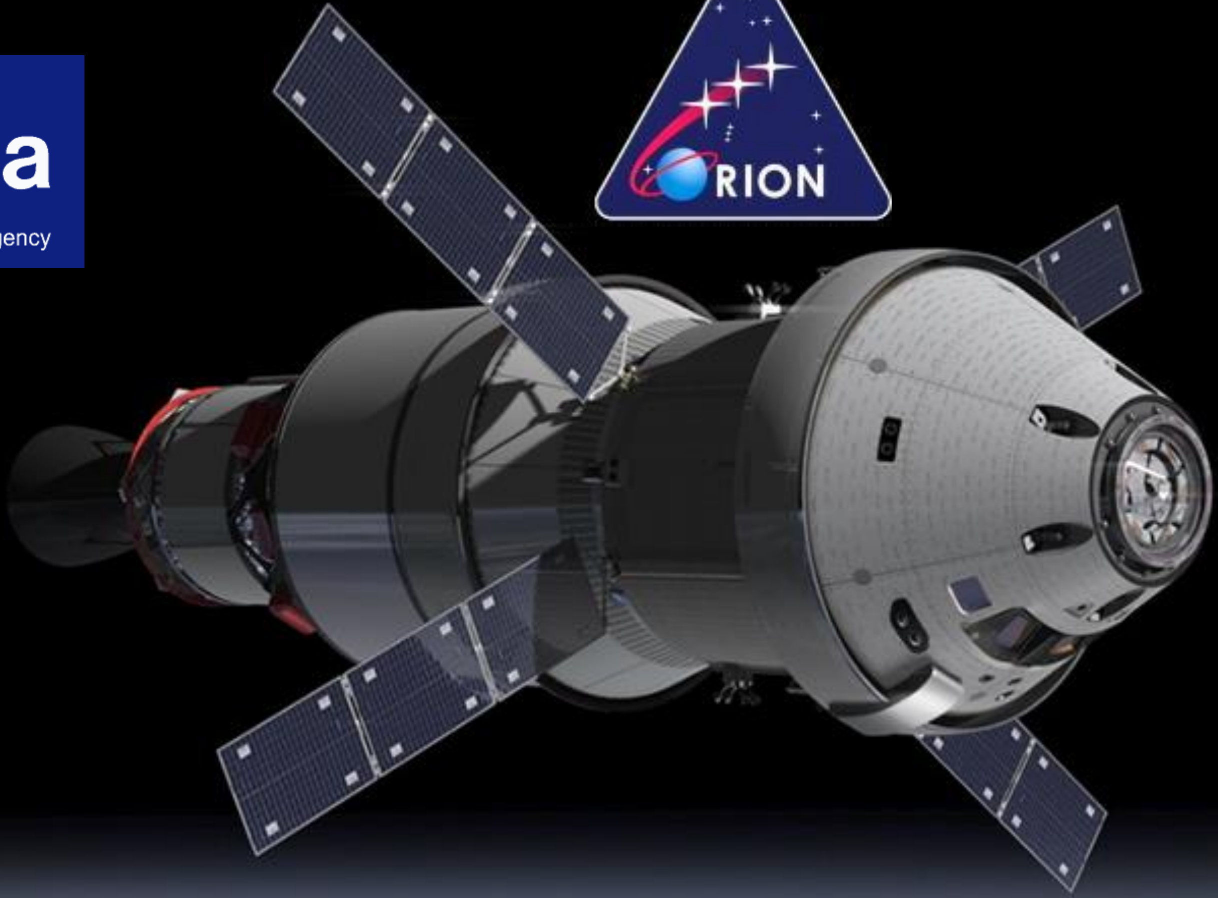
David Loyd
Institutional Safety & Mission Assurance Officer
NASA Johnson Space Center

October 17, 2018

OHS Leaders
smarter conversations

NASA Johnson Space Center
HOUSTON, TEXAS

What’s NASA Doing Now



Words of Wisdom

“It can only be attributable to human error.“

-- HAL 9000 (2001: A Space Odyssey)

NASA Risk and Safety Culture

- **NASA's Mishaps**
  - **Notable Losses in Space and on the Ground.**
  - **The Impact of Human Factors on Mishaps.**
- **NASA's Risk Management Practices**
  - **Learning how to identify "Smart Risks".**
  - **Risk Policy and Processes.**
  - **Facility Risk Control and Assessment.**
- **NASA's Safety Culture**
  - **Reducing error by cultivating skill-based behavior.**
  - **Bolstering trust throughout operations.**
  - **Measuring safety culture growth.**

NASA's Losses

Recent Mission Mishaps

Columbia STS-107, February 1, 2003:
- 7 fatalities;
- $3 Billion vehicle loss;
- 2.5 year mission impact.

NOAA N-Prime, September 6, 2003:
- $135 Million vehicle damage;
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Genesis, September 8, 2004:
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Extra-Vehicular Activity (EVA) 23 Water Intrusion, July, 16, 2013:
- Water collecting inside EMU helmet posed threat of drowning.

OCO, February 24, 2009:
- $280 Million vehicle loss;
- 5+ year mission impact.

Glory, March 4, 2011:
- $424 Million vehicle loss;
- Additional $467 million mission impact.

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NASA’s Losses

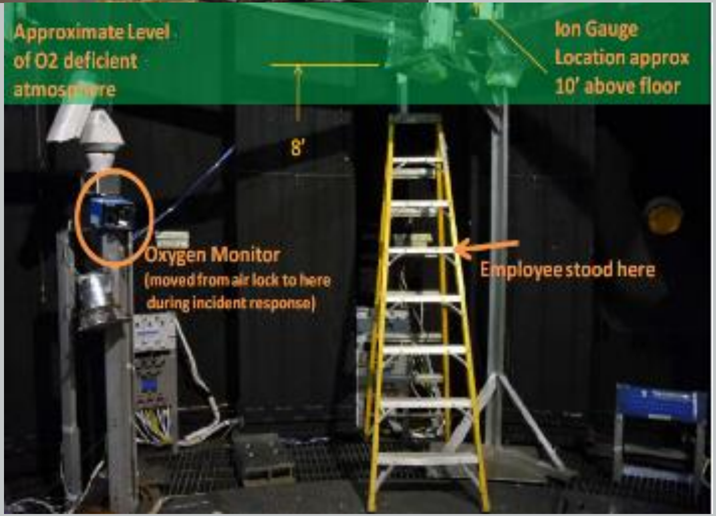
Recent Institutional Mishaps

KSC Roofing Fatality, March 17, 2006

- Subcontractor died from head injuries suffered due to fall.

JSC Custodial Fatality, January 25, 2014

- Contract employee died 2 days after suffering a fall while collecting trash.



JSC Chamber B Asphyxiation, July 28, 2010

- Shoulder injury due to asphyxiation and fall.

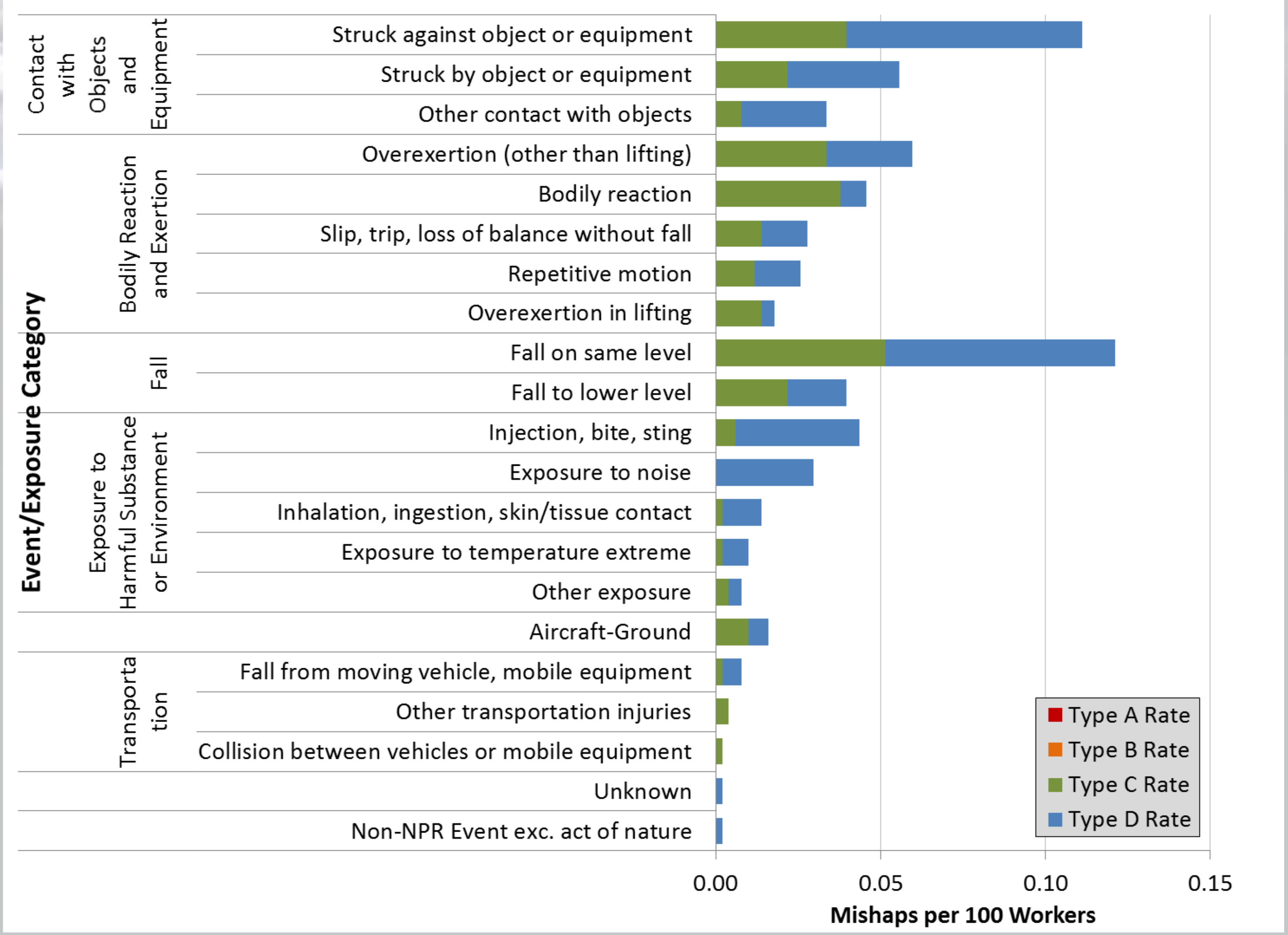
MSFC Freedom Star Tow-wire Injury, December 12, 2006

- Hospitalization due to internal injuries from impact with SRB tow-wire.

WFF CNC Injury, October 28, 2010

- Sub-dermal tissue damage due to impact from machine tool shrapnel.

NASA Injury/Illness Exposures - 2017



What is the impact of Human Factors?

- Estimates range from 65-90% of catastrophic mishaps are due to human error.
  - NASA's human factors-related mishaps causes are estimated at ~75%
- As much as we'd like to error-proof our work environment, even the most automated and complex technical endeavors require human interaction…and are vulnerable to human frailty.
- Industry and government are focusing not only on human factors integration into hazardous work environments, but also looking for practical approaches to cultivating a strong Safety Culture that diminishes risk.

Some Risk Management Philosophy…

As much as we'd like to be able to predict error, the reality is that we must measure known performance characteristics to identify vulnerabilities, mitigate greatest risk, and enable prudent response to the next accident.

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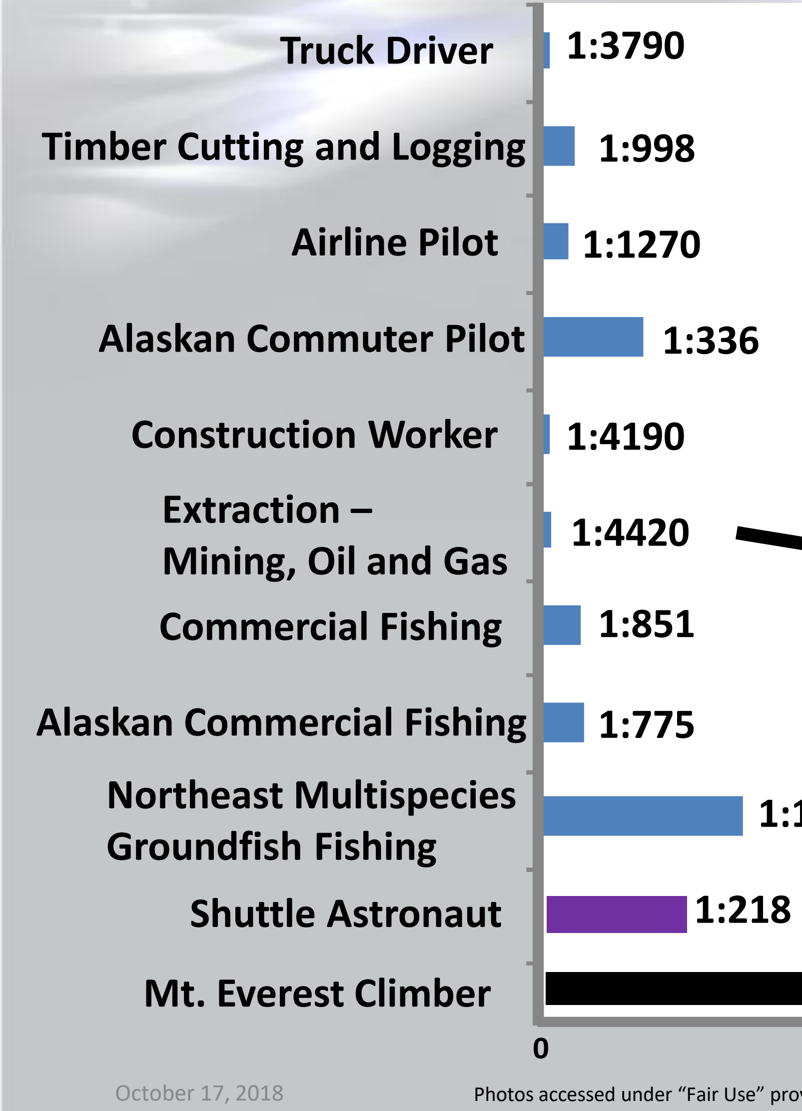
High Risk Occupations vs. Space Flight

Person-Fatality Risk Per Year



Miner risk does not include fatalities due to chronic illnesses like “black lung.”

Risk increases as “drill down” into smaller and smaller groups that drive the risk.

Shuttle Astronaut risk is a very small group that has high risk.

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Risk Tolerance & Failing Smart

NASA is known for Gene Kranz's famous quote,

"Failure is not an option."

It is not an option anyone chooses, but it is a reality we must confront.

How to identify a smart risk….

- **Can we afford the consequence of failure?**
- **Can we learn from the mistake?**
- **Can we get back up and try again?**
- **Do we own the risk in the first place?**

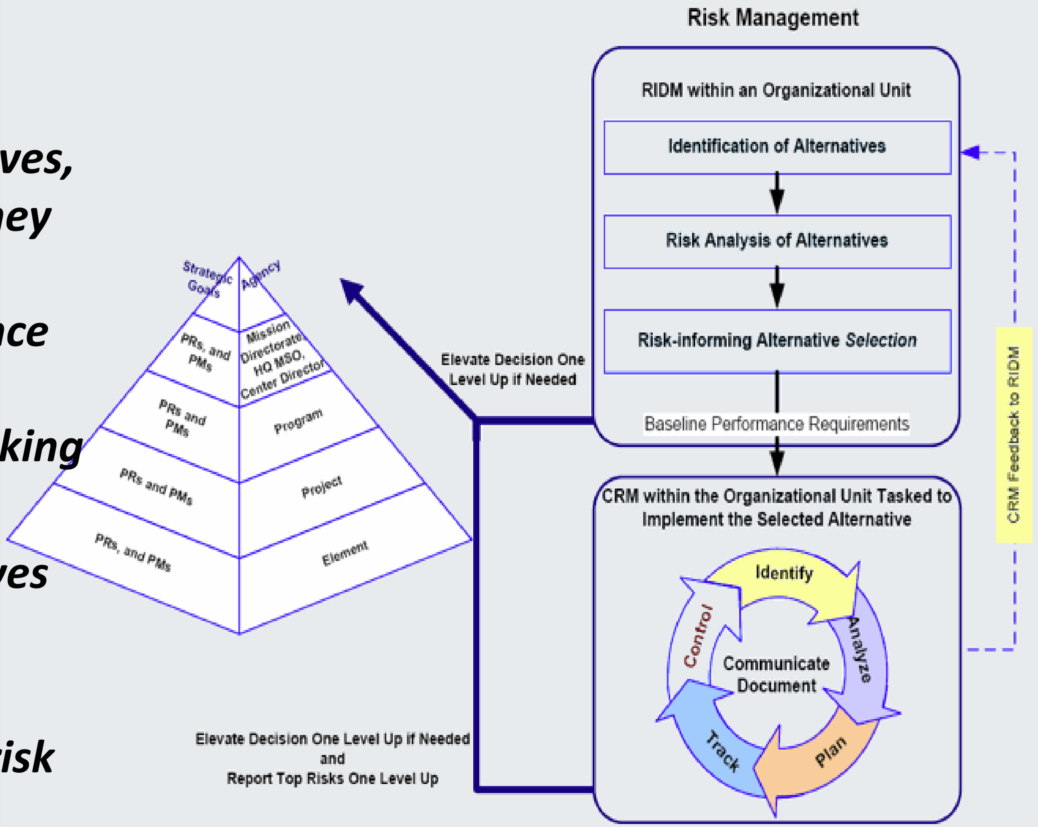
NASA's Risk Assessment Concepts & Requirements

Risk Informed Decision-Making (RIDM)* involves:

(1) Identification of decision alternatives, recognizing opportunities where they arise, and considering a sufficient number and diversity of performance measures to constitute a comprehensive set for decision-making purposes.

(2) Risk analysis of decision alternatives to support ranking.

(3) Selection of a decision alternative informed by (not solely based on) risk analysis results.



*** NPR 8000.4, *Agency Risk Management Procedural Requirements***

Risk Scorecard

LIKELIHOOD RATING

LIKELIHOOD	5	Very Likely	Expected to happen. Controls have minimal to no effect.
	4	Likely	Likely to happen. Controls have significant limitations or uncertainties.
	3	Possible	Could happen. Controls exist, with some limitations or uncertainties.
	2	Unlikely	Not expected to happen. Controls have minor limitations or uncertainties.
	1	Highly Unlikely	Extremely remote possibility that it will happen. Strong controls in place.

JSC RISK MATRIX

LIKELIHOOD						
	5	🟩	🟨	🟥	🟥	🟥
	4	🟩	🟨	🟨	🟥	🟥
	3	🟩	🟩	🟨	🟨	🟥
	2	🟩	🟩	🟨	🟨	🟨
	1	🟩	🟩	🟩	🟩	🟨
		1	2	3	4	5
		Consequences				

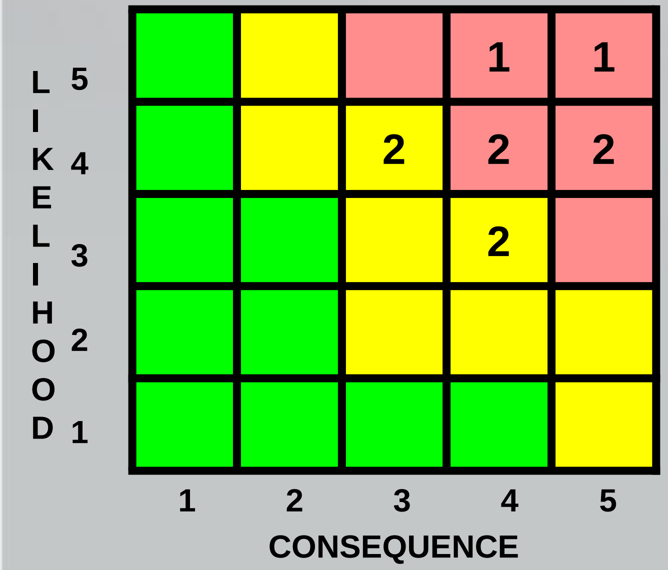
SEVERITY

- 🟥 High – Mitigate; implement new processes, change requirements, or re-baseline
- 🟨 Moderate – Manage/consider alternative processes, or Accept
- 🟩 Low – Manage within normal processes; or Close

CONSEQUENCE	*Subcategories*	1	2	3	4	5
HSE (Health, Safety, Environment)	*Personnel*	Minor injury; Minor OSHA violation	Short-term injury; Moderate OSHA violation	Long-term injury, impairment or incapacitation; Significant OSHA violation	Permanent injury or incapacitation; Major OSHA violation	Loss of life
	System, Facility	Minor damage to asset	Moderate impact or degraded performance	Loss of non-critical asset	Damage to a critical asset	Loss of critical asset or emergency evacuation
	Environment	Minor or non-reportable hazard or incident	Moderate hazard or reportable violation	Significant violation; Event requires immediate remediation	Major violation; Event causes temporary work stoppage	Catastrophic hazard
TECHNICAL	*Performance*	Minor impact to mission objectives or requirements	Incomplete compliance with a key mission objective	Noncompliance; Significant impact to mission	Noncompliance; Major impact on Center or Spaceflight mission	Failure to meet mission objectives
CENTER CAPABILITIES	*Infrastructure*	Minor impact or reduced effectiveness	Moderate impact or damage to infrastructure	Significant damage to infrastructure or reduced support	Mission delays or major impacts to Center operations	Extended loss of critical capabilities
	Workforce	Minor impact to human capital	Moderate impact to human capital	Significant impact; Loss of critical skill	Major impact; Loss of skill set	Loss of Core Competency
COST	*Organizational or CMO Impact*	<2% Budget increase or <$1M CMO Threat	2-5% Budget increase or $1M-$5M CMO Threat	5-10% Budget increase or $5M-10M CMO Threat	10-15% Budget increase or $10M-$60M CMO Threat	>15% Budget increase or >$60M CMO Threat;
SCHEDULE	--	Minor milestone slip	Moderate milestone slip; Schedule margin available	Project milestone slip; No impact to a critical path	Major milestone slip; Impact to a critical path	Failure to meet critical milestones

Institutional Risk Management

- **Risk management forums are active for individual programs and the institution, but risk assessment criteria is consistent.**
- **Though program and institutional operating budgets are separate, risks are cross-communicated to identify potential impacts.**

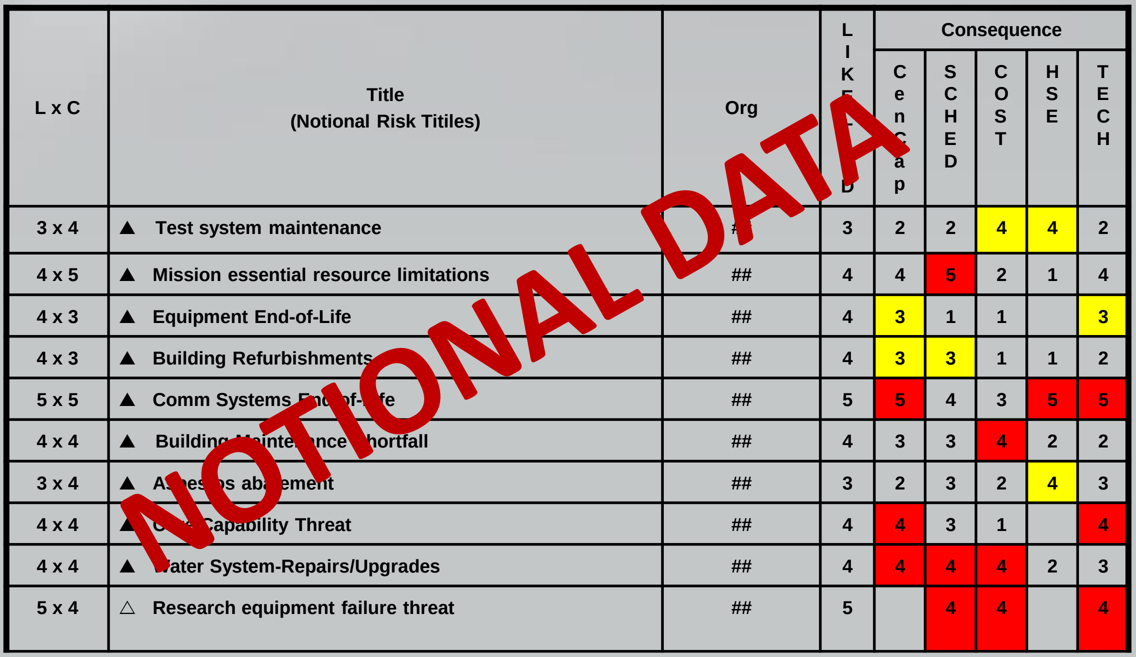


LIKELIHOOD					
5	🟩	🟨	🟥	🟥 1	🟥 1
4	🟩	🟨	🟨 2	🟥 2	🟥 2
3	🟩	🟩	🟨	🟨 2	🟥
2	🟩	🟩	🟨	🟨	🟨
1	🟩	🟩	🟩	🟩	🟨
	1	2	3	4	5
			CONSEQUENCE		

Legend

▲ Top Center Risk (TCR)

△ Proposed Top Center Risk (Proposed TCR)



L x C	Title (Notional Risk Titiles)	Org	LIKELIHOOD	Consequence				
				CenCap	SCHED	COST	HSE	TECH
3 x 4	▲ Test system maintenance	##	3	2	2	🟨 4	🟨 4	2
4 x 5	▲ Mission essential resource limitations	##	4	4	🟥 5	2	1	4
4 x 3	▲ Equipment End-of-Life	##	4	🟨 3	1	1		🟨 3
4 x 3	▲ Building Refurbishments	##	4	🟨 3	🟨 3	1	1	2
5 x 5	▲ Comm Systems End-of-Life	##	5	🟥 5	4	3	🟥 5	🟥 5
4 x 4	▲ Building Maintenance Shortfall	##	4	3	3	🟥 4	2	2
3 x 4	▲ Asbestos abatement	##	3	2	3	2	🟨 4	3
4 x 4	▲ Core Capability Threat	##	4	🟥 4	3	1		🟥 4
4 x 4	▲ Water System-Repairs/Upgrades	##	4	🟥 4	🟥 4	🟥 4	2	3
5 x 4	△ Research equipment failure threat	##	5		🟥 4	🟥 4		🟥 4

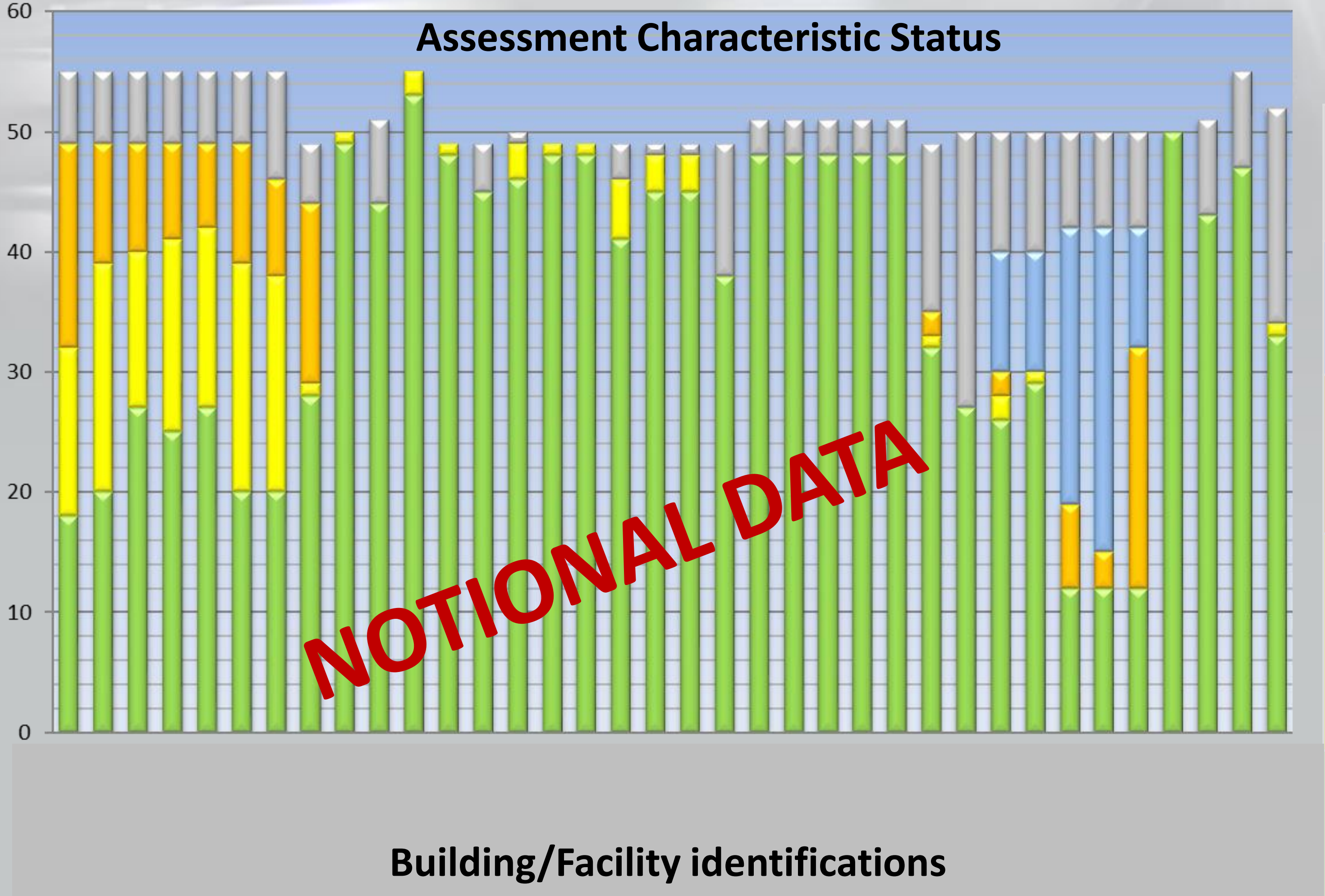
Process Measures for High-Risk Facilities

- **Industry and government organizations have recognized the value of monitoring leading indicators to identify potential risk vulnerabilities.**
- **NASA has adapted this approach to assess risk controls associated with hazardous, critical, and complex facilities.**
- **NASA's facility risk assessments integrate commercial loss control, OSHA Process Safety, API Performance Indicator Standard, and NASA Operational Readiness Inspection concepts to identify risk control vulnerabilities.**

Examples of leading measure areas for high-risk facilities include:

- ✓ **Maintenance and system integrity conditions;**
- ✓ **Operational qualifications;**
- ✓ **Challenges to safety systems and monitoring equipment;**
- ✓ **Communication and reporting system conditions;**
- ✓ **Accuracy of configuration management;**
- ✓ **Maintenance of operational procedures and emergency response plans.**

Facility Safety Risk Monitoring



Assessment Characteristic Key

Not Applicable	Elements of assessment are not applicable to the associated facility mission.
HATS Closed: Conforms	Items identified as nonconforming were resolved.
*** Non-conformance**	Documentation does not exist to support the checklist requirements.
Partially conforms	Significant information is available, but does not meet the intent of risk control, or it is out of date or unavailable.
Conforms	Documentation is available with the required information to meet checklist intent.

*** A nonconformance is tracked until closure. Partial nonconformances represent opportunities for risk reduction but are not followed up until the next scheduled assessment.**

Minimizing Human Error and Cultivating a Reduced Risk Environment

Rasmussen's 3 Human Responses to Operator Information Processing

1. **Skill-based**: requires little or no cognitive effort.
2. **Rule-based**: driven by procedures or rules.
3. **Knowledge-based**: requires problem solving/decision making.

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"The fewer rules a coach has, the fewer rules there are for players to break."

John Madden

"Successful design is not the achievement of perfection but the minimization and accommodation of imperfection."

Henry Petroski

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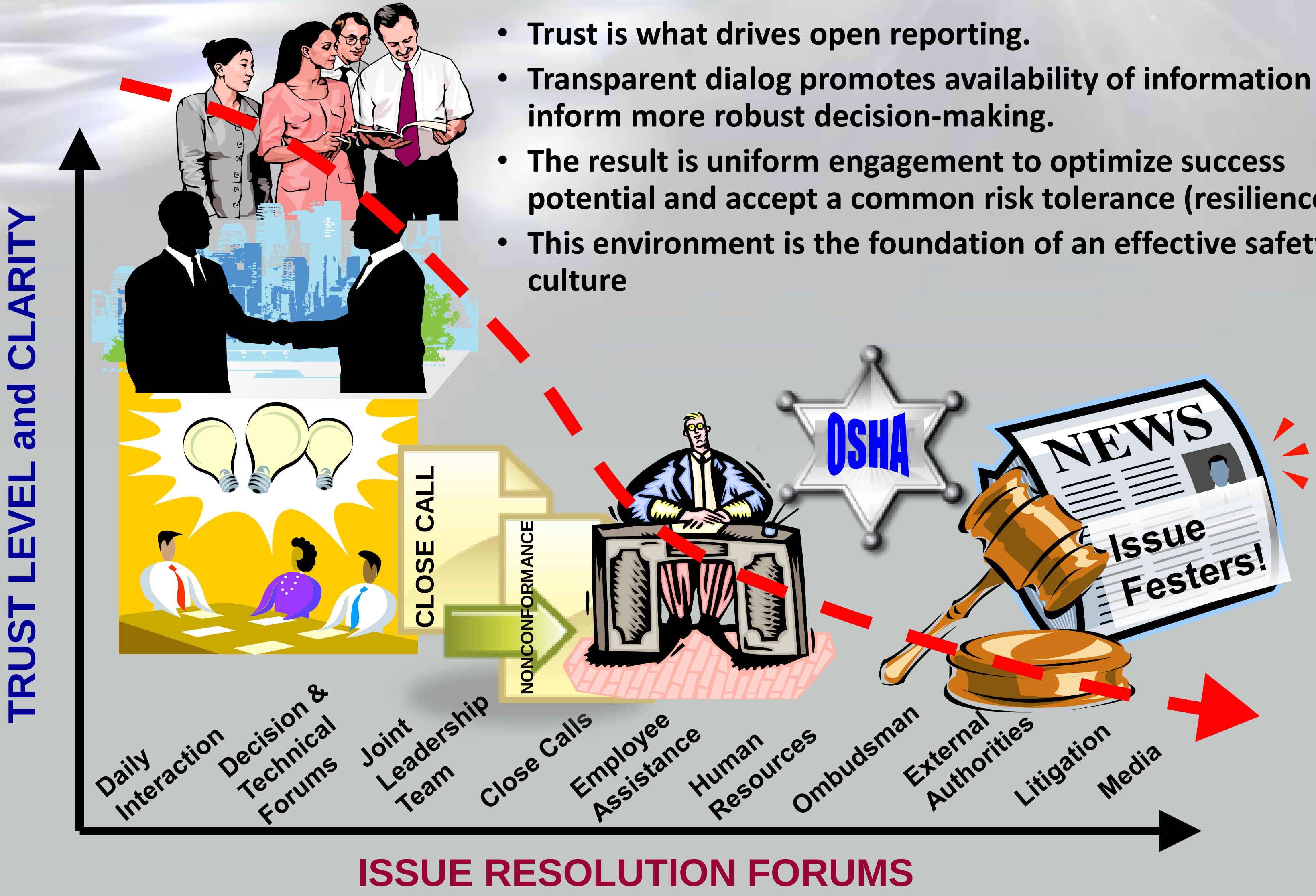
Trust and Transparency Builds Common Risk Tolerance

- **Trust is what drives open reporting.**
- **Transparent dialog promotes availability of information to inform more robust decision-making.**
- **The result is uniform engagement to optimize success potential and accept a common risk tolerance (resilience).**
- **This environment is the foundation of an effective safety culture**



How Safety Culture Promotes Operational Excellence

- By advocating a pervasive Safety Culture, we can provide our workforce with:
  - Clear emphasis on continuous learning;
  - Encouragement to develop intuitive personal values;
  - Guidelines for decision-making behavior that focuses on long-term success;
  - Reinforcement to build trust by reporting and communicating concerns and ideas.
- Practicing an effective Safety Culture:
  - Builds Skill-based and Knowledge-based response mechanisms;
  - Reduces the emphasis on Rule-based response;
  - And breaks down barriers to Trust.

NASA's Safety/Risk Culture Model

"An environment characterized by ***safe attitudes and behaviors modeled by leaders*** *and* ***embraced by all*** *that fosters an atmosphere of* ***open communication****,* ***mutual trust****,* ***shared safety values and lessons****, and confidence that we will* ***balance challenges and risks*** *consistent with our core value of safety to successfully accomplish our mission."*

An effective safety culture is characterized by the following subcomponents:

- **Reporting Culture - We report our concerns**
- **Just Culture - We have a sense of fairness**
- **Flexible Culture - We change to meet new demands**
- **Learning Culture - We learn from our successes and mistakes**
- **Engaged Culture - Everyone does his or her part**

Catastrophic Event Impact

Using the Safety Culture Model to Analyze NASA's History

Columbia – February 1, 2003

Challenger – January 28, 1986

Reporting – With both tragedies, launch process deficiencies, such as O-ring susceptibility in cold temperatures (Challenger) and foam shedding (Columbia), were passively reported problems, yet were not considered serious hazards.

Just – Some engineers were reluctant to raise concerns when faced with a return of an "in God we trust - all others bring data" attitude.

Flexible – With both incidents, the Shuttle Program was experiencing schedule pressure challenges.

Learning – With "normalization of deviance," O-ring burn-through and foam impact had become classified as "in-family" and as a negligible risk.

Engaged – NASA management lacked involvement in critical discussions.

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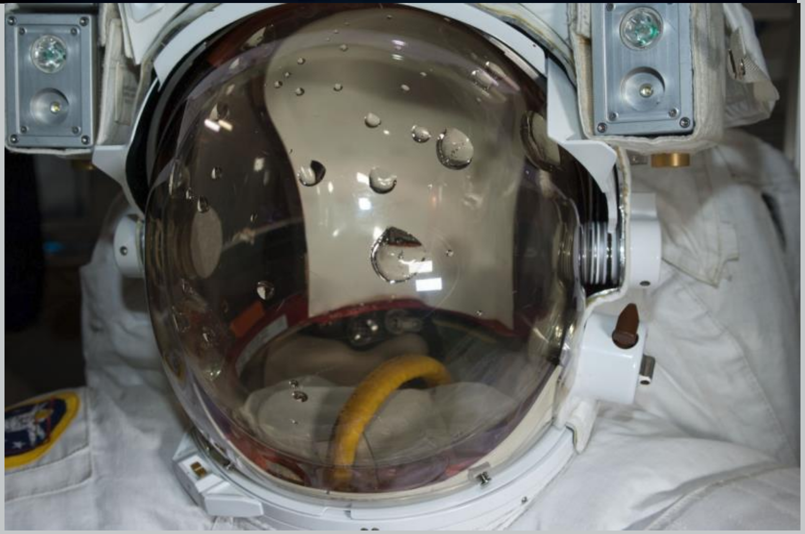


Extra-Vehicular Activity (EVA) 23 Water Intrusion – July 16, 2013

Reporting – Previous reports of EMU Suit leakage had been attributed to drink-bag leakage. Reporting and investigating subsequent leakage was perceived of limited value.

Just – In addressing on-orbit anomalies, there was uncertainty between the defined roles and responsibilities of each of the organizations that participate in real-time operations.

Flexible – Extensions in EMU maintenance frequency led to more cumbersome EMU hardware repair, constraining flexibility in responding to EMU-related anomalies.

Learning – Attrition had depleted knowledge of EMU suit legacy, lessons, and inherent limitations.

Engaged – Throughout the EVA 23 activity and associated anomaly investigation, engagement was exceptional.

NASA Safety Culture Model Applied to Deepwater Horizon

Deepwater Horizon – April 20, 2010

Reporting – Procedures were subjected to last-minute distribution, last minute decision.

Just – Concerns of rig workers regarding test results were muted, not heeded or explored .

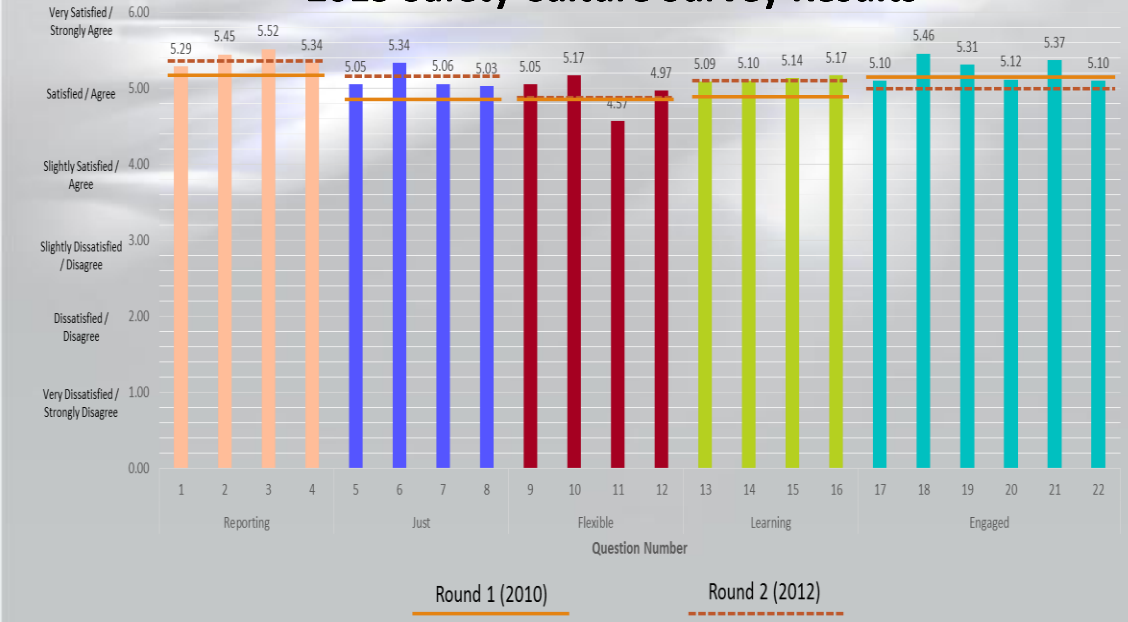
Flexible – All involved seemed prepared to exercise flexibility, but this may be indicative of insufficient process discipline.

Learning – Invalid confidence in new slurry, vents from Mud-Gas Separator (MGS) allowed gas to enter rig spaces, insufficient planning for contingencies.

Engaged – Incorrect reading of pressure tests, lack of recognition or timely control action related to kicks, diverted flow through MGS instead of overboard, reluctance to activate Blow-Out Preventer (BOP), reluctance to activate the Emergency Disconnect System, BOP testing and maintenance.

Measuring Safety Culture

2015 Safety Culture Survey Results



JSC R1 through R3 Comment Quality Analysis

"Quality" is equivalent to Likert Value associated with received comments.
"Engagement" is the average number of comments per SCS participant.

Comment Temperature Perspectives

HOT

"Eliminate the recalcitrant dinosaur dictators"

WARM

"Emphasis on purpose of safety measures, not just filling out a form or checking a box."

TEPID

"Watch out for everyone"

"Communication"

COOL

"Keep doing what you are doing. We are constantly being reminded of Safety and its importance."

Reducing Risk Vulnerabilities

- NASA, like the other hazardous industries, has suffered very catastrophic losses.
- Human error will likely never be completely eliminated as a factor in our failures.
- Acknowledging human frailty and the potential for failure bolsters our ability to manage risks and mitigate the worst consequences.
- Building an effective Safety Culture bolsters skill-based performance that minimizes risk and encourages operational excellence.

Backup Charts

Columbia STS-107, February 1, 2003:

7 fatalities;
$3 Billion vehicle loss;
2.5 year mission impact.

Kalpana Chawla
Rick D. Husband
Laurel B. Clark
Ilan Ramon
Michael P. Anderson
David M. Brown
William C. McCool

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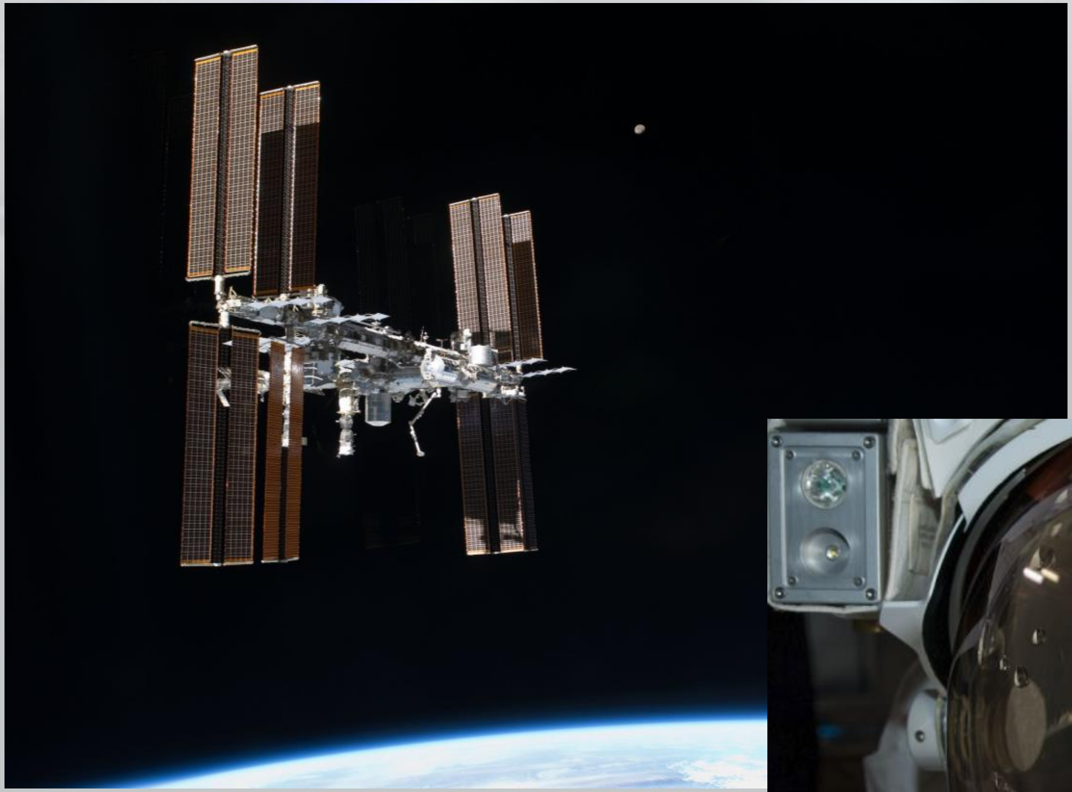

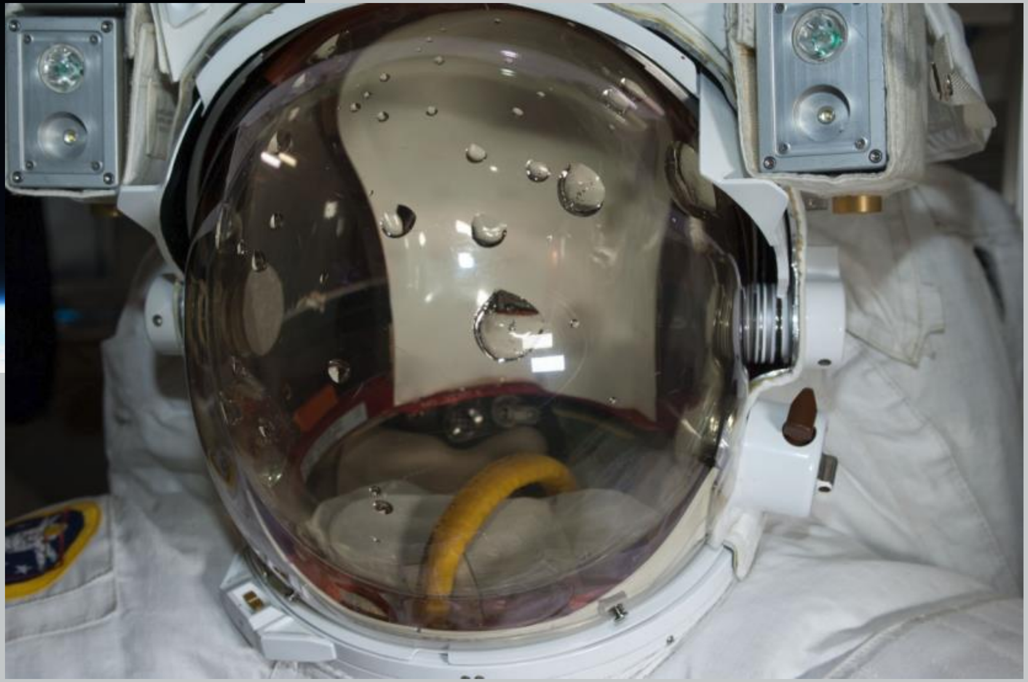

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