COE CST Fifth Annual Technical Meeting

TASK 320: Commercial Spaceflight Risk Assessment and Communication

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University of Colorado Boulder

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Team Members

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(no photo)

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Task Description

- **New Task 320 (2015-2016) Commercial Space Flight Risk Assessment and Communication**

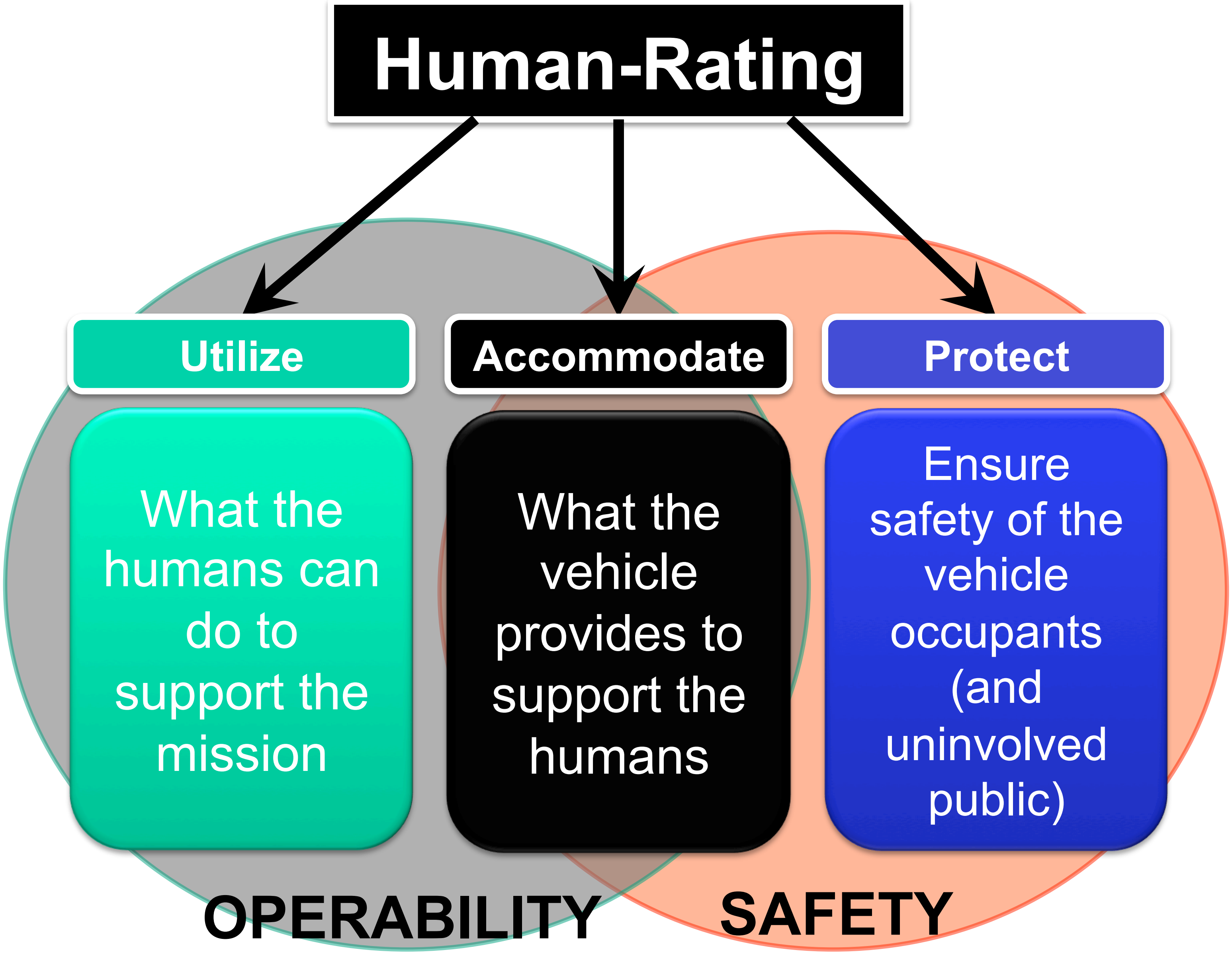
- *Prior Task 184 Human-Rating of Commercial Spacecraft (2011-2014) served as a baseline for this current research by addressing spacecraft human-rating processes and associated terminology*

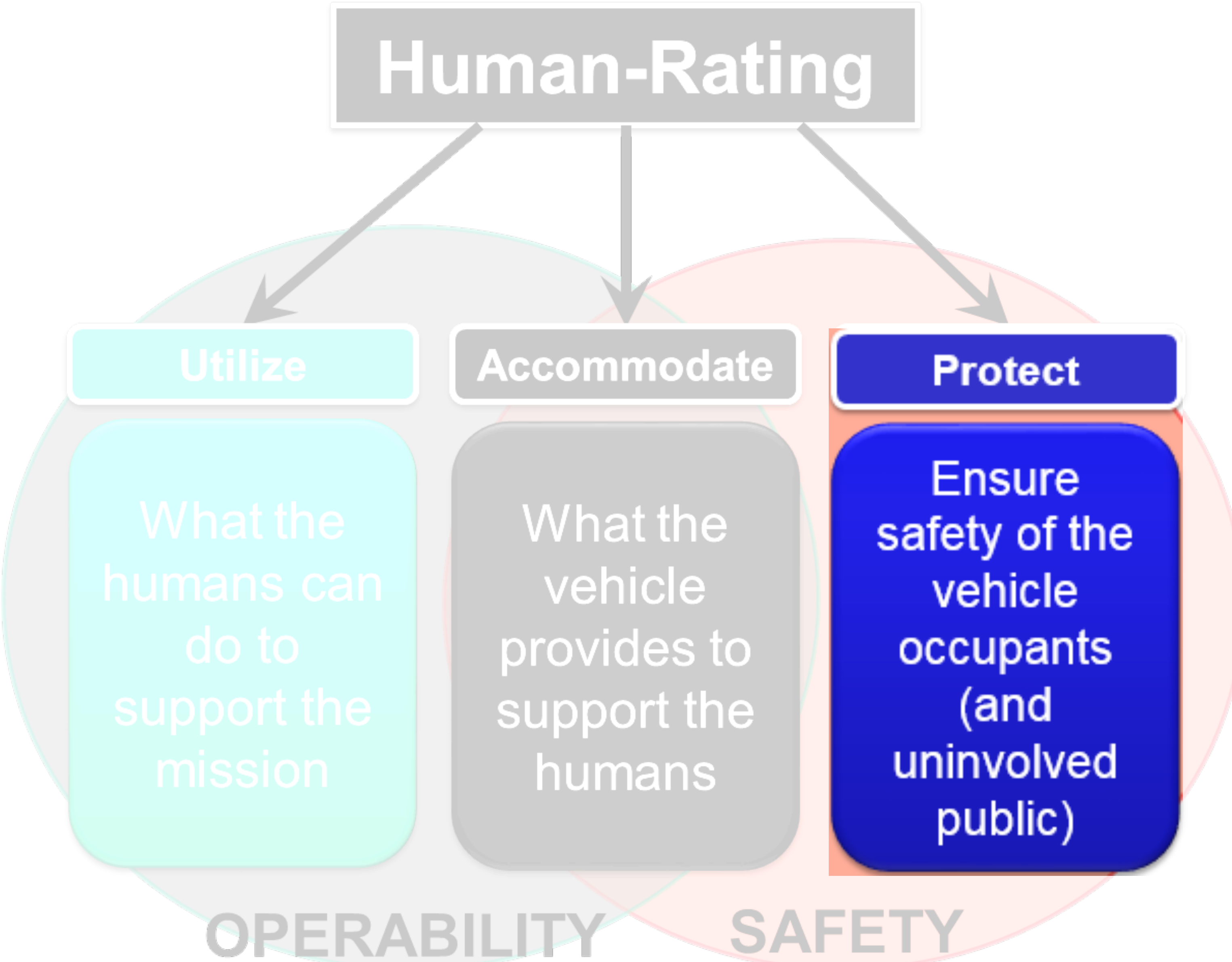
Prior Task 184 Results: COE Reports and Contributions to FAA Documents

1. Safe Return to Earth, 2012
2. Human Spaceflight Terminology and Definitions, 2013
3. Human Spaceflight Safety Terms and Definitions, 2013
4. Human Spaceflight Safety Perspectives, 2013
5. FAA Human-Rating Ground Rules and Assumptions Document (pre-decisional, 2013)
6. FAA Established Practices for Human Spaceflight Occupant Safety draft (7/31/13), with rationale (9/23/13)
7. Thoughts and Considerations on Necessary Levels of Care for Commercial Spaceflight Transportation, 2014
8. FAA Recommended Practices for Human Space Flight Occupant Safety Version 1.0, (8/27/2014)

Prior Task 184 Results: Publications

1. Fanchiang, C. **Characterization and Evaluation of Manned Spacecraft Operability Factors**. *63rd IAC*, Naples, Italy, Oct 2012
2. Fanchiang, C., Johnson, M., and Ocampo, R. (2012) **Evaluation of Commercial Human Spaceflight Laws and Regulations in the United States**, IAC-12-D6.1.7 *63rd IAC*, Naples, Italy, Oct 2012
3. Klaus, D.M., Fanchiang, C. and Ocampo, R.P. (2012) **Perspectives on Spacecraft Human-Rating**. *AIAA* 2012-3419
4. Ocampo, R.P. and Klaus, D.M. (2013) **A Review of Spacecraft Safety: from Vostok to the International Space Station**. *New Space* 1(2): 73-80
5. Klaus, D.M., Ocampo, R.P. and Fanchiang, C. (2014) **Spacecraft Human-Rating: Historical Overview and Implementation Considerations**. *IEEE Aerospace Proceedings* (978-1-4799-1622-1/14, no. 2272)
6. Neis, S.M. and Klaus, D.M. (2014) **Considerations toward Defining Medical 'Levels of Care' for Commercial Spaceflight**. *New Space*, December 2014, **2(4)**: 165-177


Human-Rating
Utilize
Accommodate
Protect
What the humans can do to support the mission
What the vehicle provides to support the humans
Ensure safety of the vehicle occupants (and uninvolved public)
OPERABILITY
SAFETY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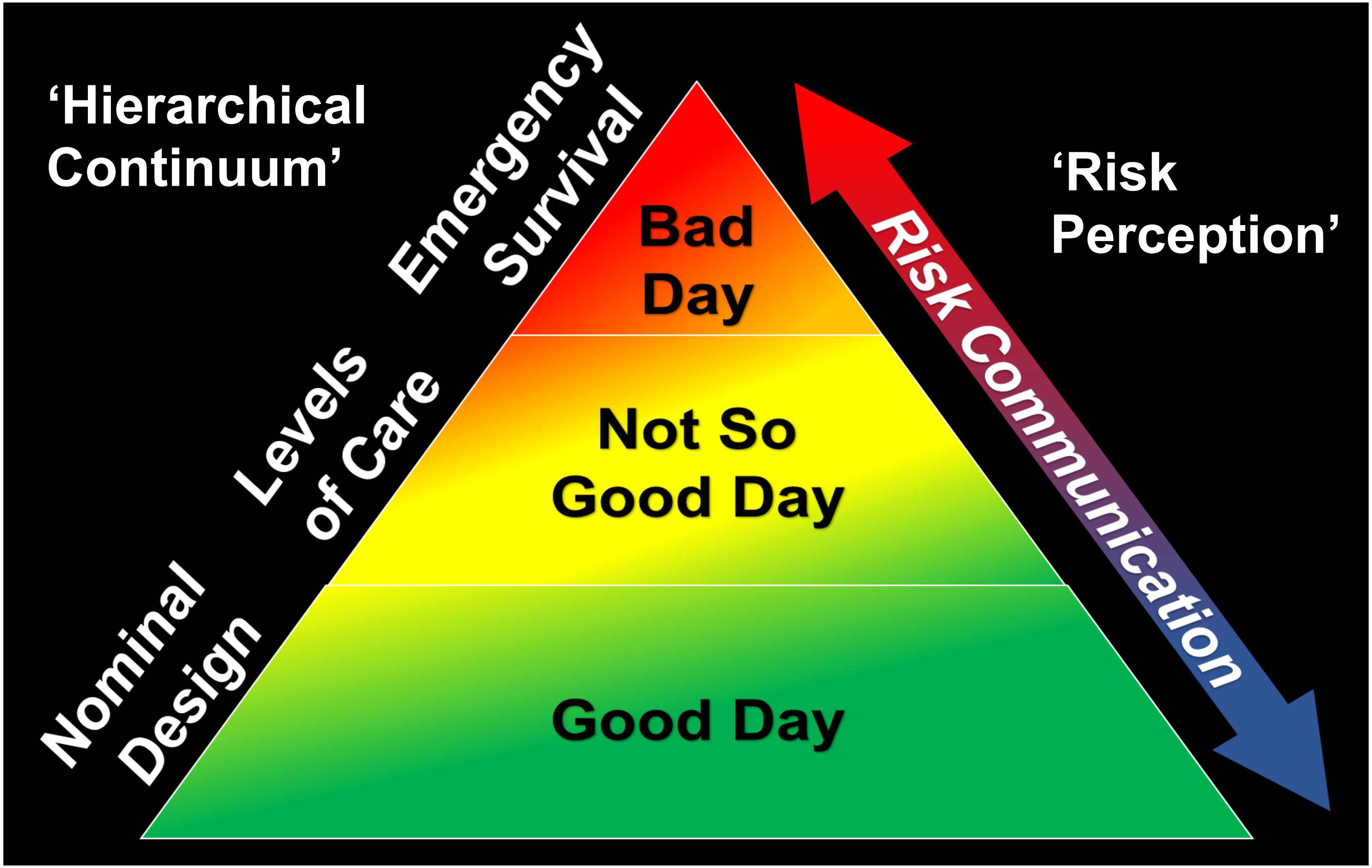
Overall Task 320 Framework



Overall Task 320 Framework

- **Human-Rating Guidelines** – defined to help ensure likelihood of a ‘good day’ through risk mitigation and fault tolerant vehicle design
- **Medical ‘Levels of Care’** – intended to address minor (non-life threatening) injury or illness that might be considered a ‘not so good day’
- **Emergency Survival** – allow potential to deal with life-threatening illness/injury or recover from catastrophic vehicle failure to keep a ‘bad day’ from getting worse…

Task 320 Description

- **Commercial Spaceflight Risk Assessment and Communication**

- **Characterize** and **predict** risk factors of spaceflight and other transportation or adventure activities
- Develop effective, understandable ways to **identify**, **communicate** and **mitigate** the risks of spaceflight to space flight participants and the general public
- Summarize best practices with associated design safety **verification**

Schedule

June 1, 2015 through May 31, 2016

1) Provide a systematic framework for **characterizing risk** as a function of phase of spaceflight in terms of the range of scenarios from nominal ops to catastrophic vehicle failure and/or human illness or injury

2) Assess **risk prediction strategies**

3) Review prior spaceflight and terrestrial analogies to **effectively communicate risk** of space transportation to the public in a balanced, informing manner

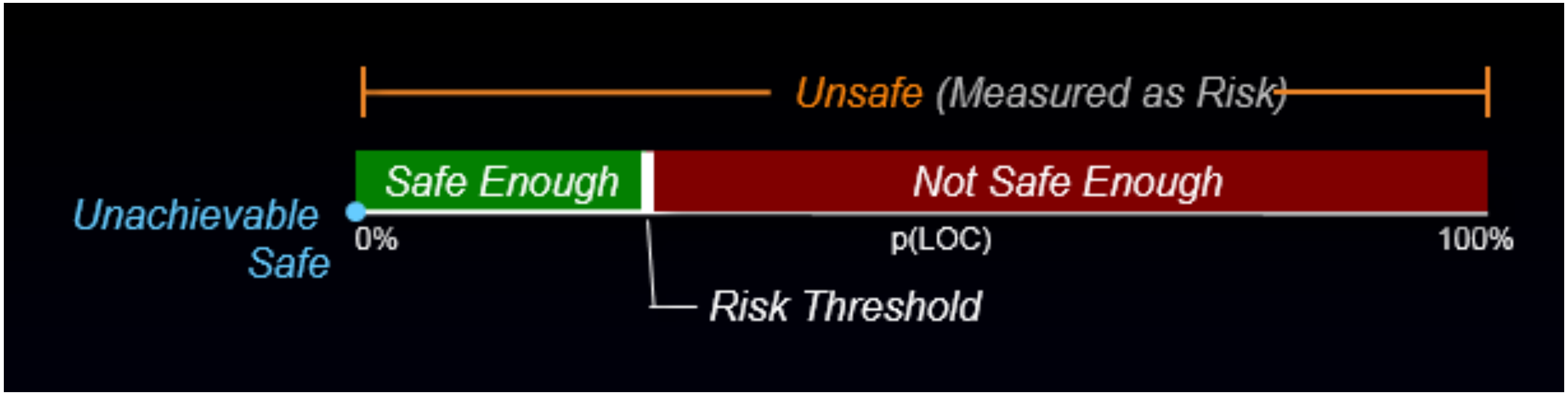
4) Characterize **verification processes** aimed at ensuring the defined level of reliability (risk mitigation) is achieved for a given vehicle

Goals

- What does it mean for a spacecraft to be "Safe Enough"?
- How can "Safe Enough" be assessed using spacecraft risk progression statistics?
- How can we effectively communicate the relevant risks to space flight participants?
- What type of pre-hospital medical equipment and protocols are needed to assess and treat in-flight illness or injury and how is their implementation verified?

What is 'safe enough'?

Publication in prep for New Space



UNACHIEVABLE SAFE: System is free from all catastrophic hazards. Given that no practical (e.g. non-theoretical) system can ever be free of such hazards, this state is unachievable[2].

SAFE ENOUGH: System exhibits a mean probabilistic Loss of Crew—p(LOC)—value less than or equal to an established risk threshold (with a given level of statistical certainty)[2].

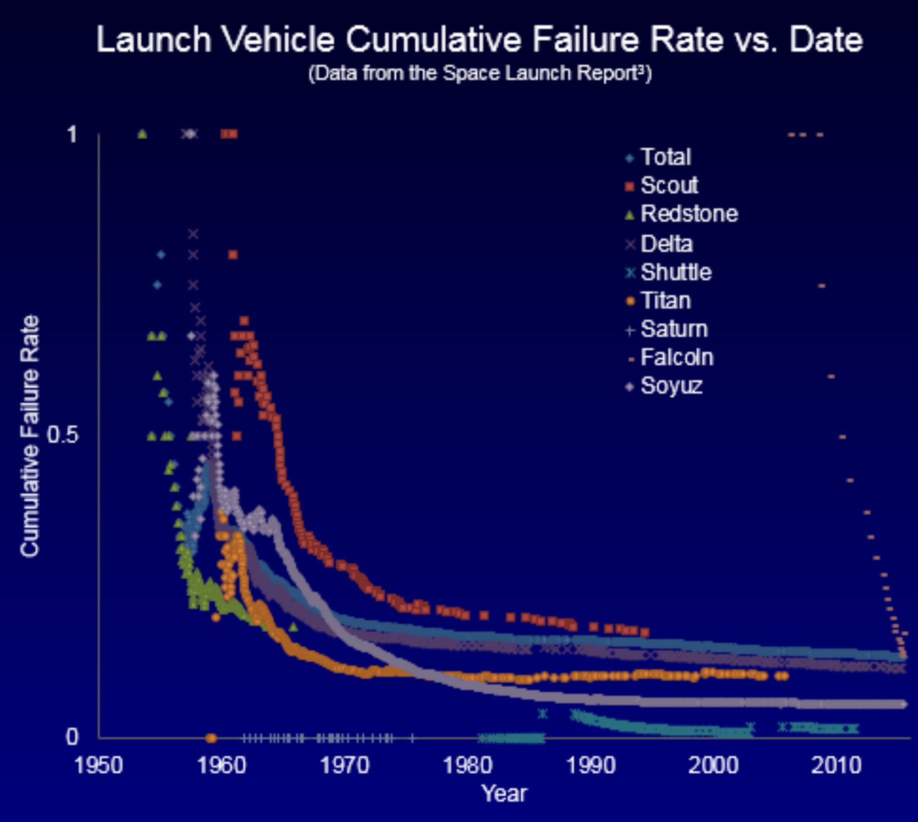
RISK THRESHOLD: A p(LOC) value chosen to distinguish "Safe Enough" from "Not Safe Enough". This value should attempt to balance what is acceptable with what is achievable[2].

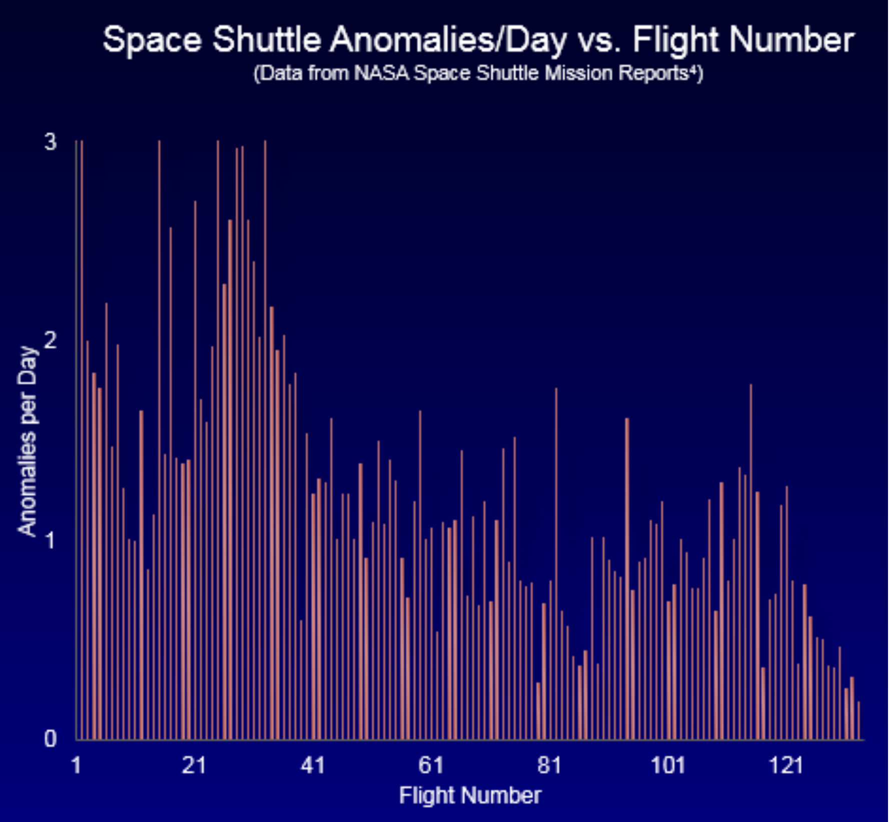
UNSAFE: One or more catastrophic hazard(s) can occur. The likelihood of any one of these hazard(s) occurring is directly proportional to the degree to which the system is "Unsafe"[2].

NOT SAFE ENOUGH: System that exhibits a mean p(LOC) value greater than an established risk threshold (with a given level of statistical certainty)[2].

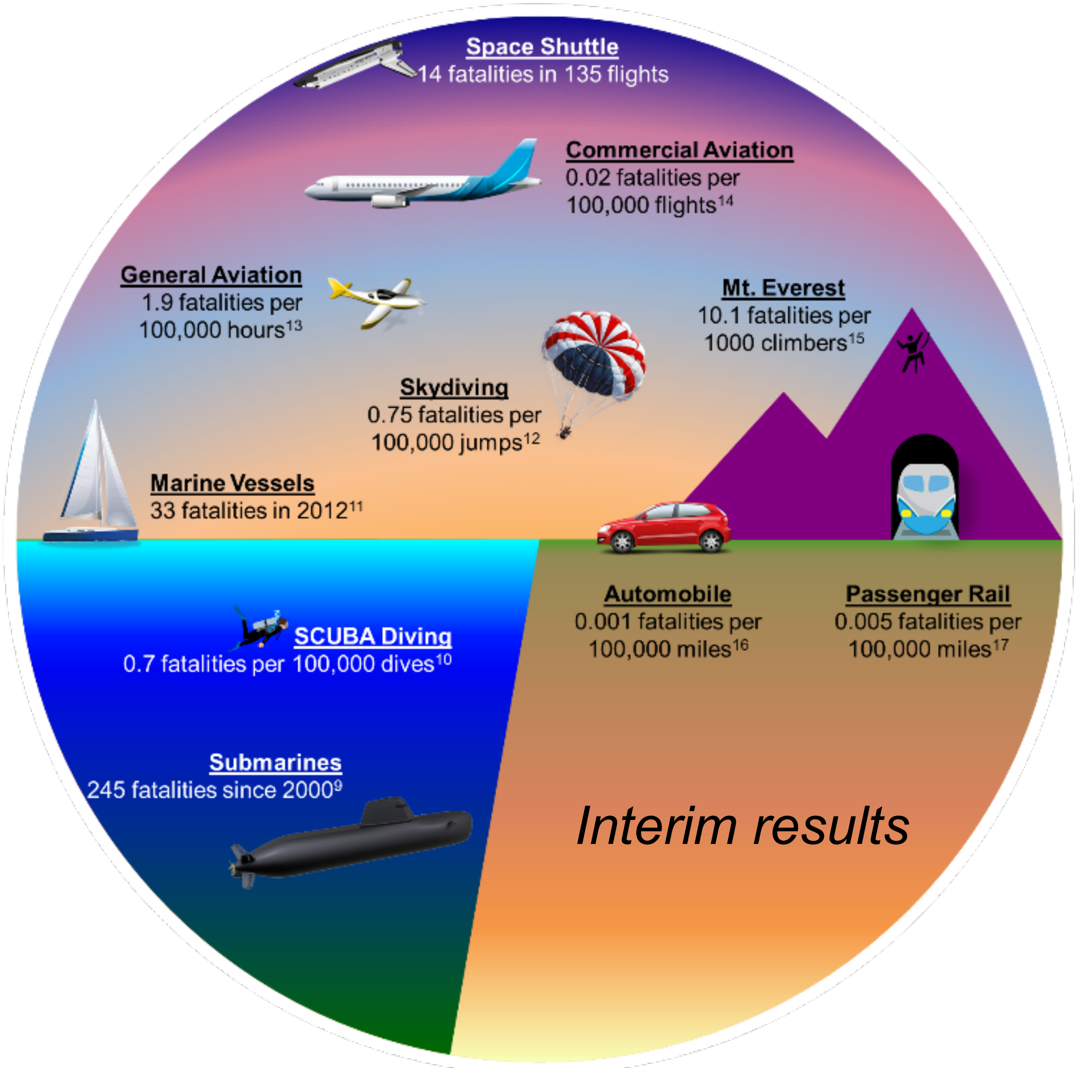
RISK: The degree to which a system is unsafe[2].

Risk Progression Analysis





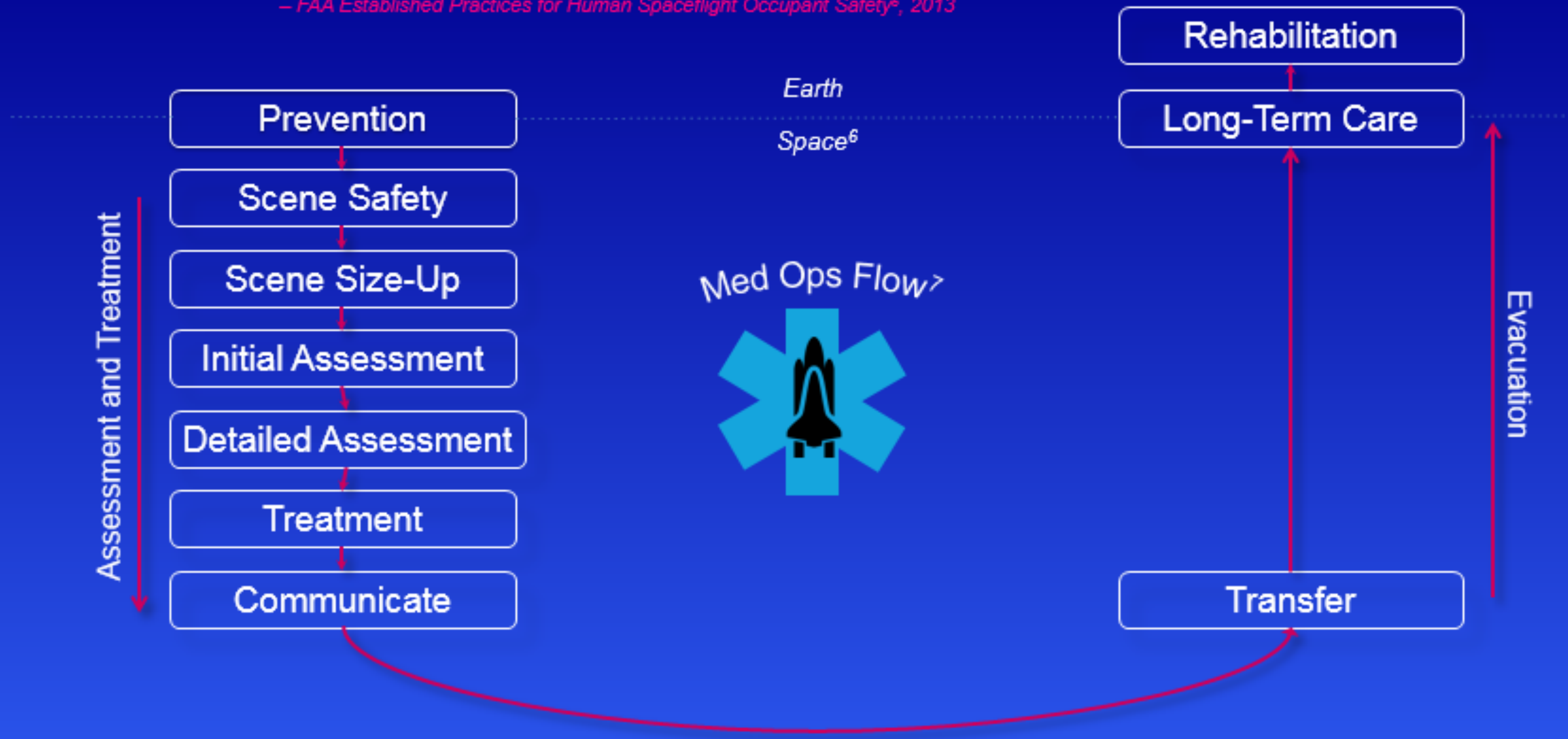
Relative Risk Communication



Inflight Illness or Injury

"Training for flight crews should include the use and location of on-board medical equipment and supplies..."

– FAA Established Practices for Human Spaceflight Occupant Safety[5], 2013



Medical ‘Levels of Care’ for CST

- **Determining appropriate ‘Level of Care’ for commercial space flights should consider**
  - unique risks to each phase of suborbital or orbital flight
  - means of accommodating safety and medical concerns

- **Implementing an appropriate ‘Level of Care’**
  - function of vehicle design and operations, including available equipment and personnel training

Results to date

- Ocampo, R.P. and Klaus, D.M. **A Quantitative Framework for Defining "How Safe is Safe Enough?" in Crewed Spacecraft** [in prep for submission to *New Space*]

Conclusions and Future Work

- **The goal is not to ensure absolute freedom from hazards (not possible), rather an attempt to identify and minimize the risks incurred in the presence of hazards and failure potentials.**
- Risk is conveyed in terms *probabilistic prediction* of true (or actual) risk and ultimately realized as *actuarial outcome*.
  - Actual risk decreases over time as hazards are identified, mitigated, and controlled.
  - Actuarial data from U.S. and Soviet launch vehicles corroborate this claim, and indicate that risk tends to stabilize after a period of roughly 35 launches
  - Assessment of risk also becomes more refined over time as analysts gain both insight and experience with the system.
  - Risk uncertainty, as measured by PRA values, also showed a decline over the course of the Space Shuttle program. This suggests that as the total number of launches increase, the more accurately analysts can assess risk.

Conclusions and Future Work

- Risk perception strategies for effective communication to the general public in terms of more common, relevant terrestrial experiences will be addressed through literature review and analysis
- Risk mitigation and verification strategies will be evaluated
- Human health-related vehicle design concerns of interest within the proposed ‘Good Day, Not So Good Day, Bad Day’ framework will be coordinated with Dr. Jim Vanderploeg and colleagues at UTMB

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