COE CST Sixth Annual Technical Meeting

Task 320: Commercial Spaceflight Risk Assessment and Communication

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University of Colorado Boulder

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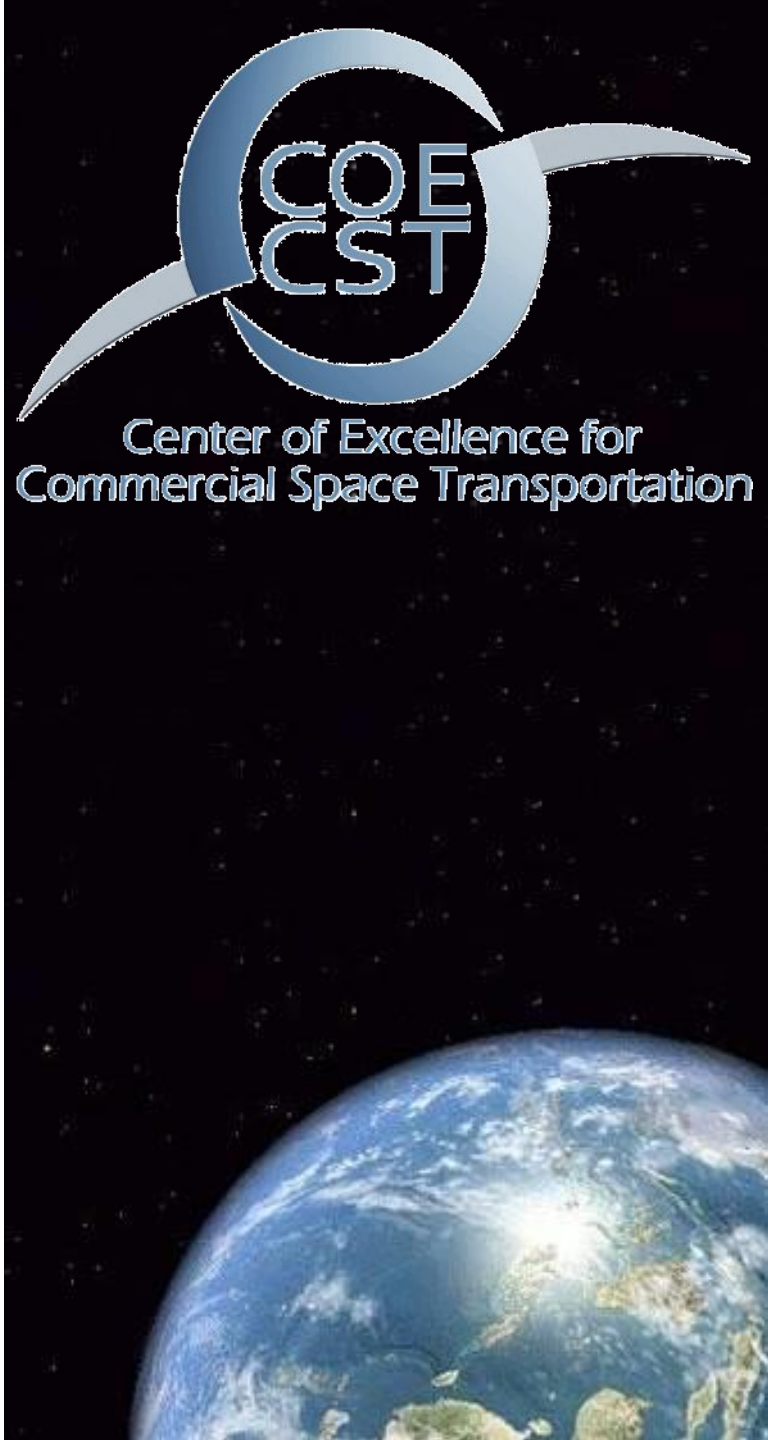


Task 320 Team Members

- Principal Investigator: **David Klaus**
- PhD Student: **Robert Ocampo**

graduated May 2016

University of Colorado Boulder

- FAA AST TM: **Henry Lampazzi** *(no photo)*

Task Description

- **Task 320 (2015-2017) Commercial Space Flight Risk Assessment and Communication**

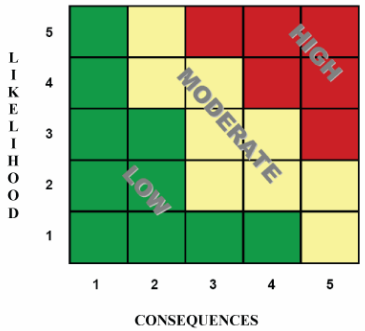
- *Builds on prior Task 184 Human-Rating of Commercial Spacecraft (2011-2014) - Accommodate, Utilize and Protect*
  - *Neis, S.M. and Klaus, D.M. (2014) Considerations toward Defining Medical 'Levels of Care' for Commercial Spaceflight. New Space, December 2014, 2(4): 165-177*
  - *Klaus, D.M., Ocampo, 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)*
  - *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*
  - *Klaus, D.M., Fanchiang, C. and Ocampo, R.P. (2012) Perspectives on Spacecraft Human-Rating. AIAA-2012-3419*

Task Description

- Commercial space travel, as with any mode of transportation, inherently introduces some degree of risk to the onboard occupants and uninvolved public
  - Risks arise from potential for vehicle failures, environmental hazard interactions, or human errors
  - Outcomes range from discomfort or incomplete objectives, up to health impacts and loss of life
  - Potential for onboard illness or injury unrelated to vehicle failure can also be considered as a risk
  - Risks that cannot be mitigated must be characterized and effectively communicated to crewmembers and spaceflight participants

Task Description

- Process of identifying, quantifying and mitigating risk is typically accomplished using various techniques in systems engineering design and through operational protocols.
- Implementation of risk reduction is generally vehicle-specific
  - Design for Minimum Risk (DFMR)
  - Design for Demise (D4D)
  - Hazard Analysis, MTBF, FMEA, PRA, Fault Tree, etc.
  - Characterized as Likelihood vs. Consequences



- Proposed more generally applicable design-independent aspects defined within high-level categories tentatively titled:

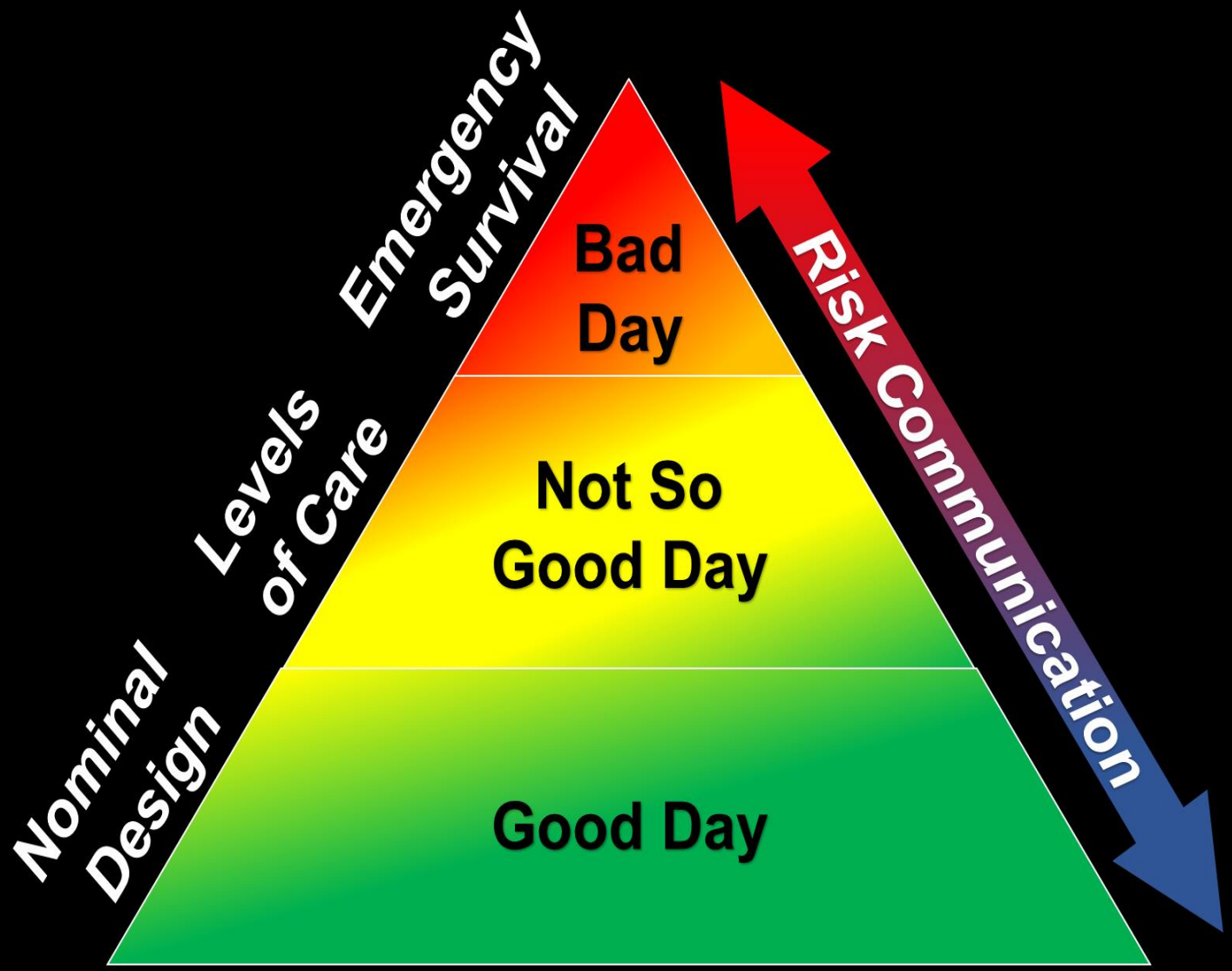
‘**Good Day**, **Not so Good Day**, and **Bad Day**’

Task Description

- ***Good Day*** **–necessary elements in place for a safe and successful flight**
  - 'human-rated' system
  - preflight participant 'fitness to fly' and medical certification for the crew
  - no occurrence of injury or illness during the flight

- ***Not so Good Day*** **– successful flight accomplished with 'fault tolerance'**
  - non-catastrophic vehicle failure, workaround available
  - minor (non-life threatening) injury or illness, onboard medical 'Level of Care' provided

- ***Bad Day*** **– emergency survival to keep a 'bad day' from getting 'worse'**
  - catastrophic vehicle failure or occurrence of a life threatening illness or injury
  - planned emergency scenarios such as aborts, bailouts, pressure suits, etc.
  - characterization of human tolerance limits associated with potentially extreme environments experienced in the event of such maneuvers
  - ensure appropriate medical care is on standby at the landing site


Emergency Survival
Levels of Care
Nominal Design
Bad Day
Not So Good Day
Good Day
Risk Communication

Task Description

- **Year 1 of Task 320 (June 1, 2015 through May 31, 2016)**
  - Defined relative degrees of ‘safe’ and means of quantifying ‘acceptable’ levels of risk for commercial spaceflight
  - Framework developed to deal with inflight medical issues
  - Comparative perspective offered for understandable ways of communicating risks of spaceflight to the general public
- **Year 2 of Task 320 (June 1, 2016 through May 31, 2017)**
  - Characterize and evaluate risk reduction strategies associated with each phase of the various commercial space flight profiles, with emphasis on medical level of care
  - Outcome intended to facilitate the ability of commercial launch operators and the FAA to fulfill their responsibilities related to informed consent

Alignment with FAA AST Goals

- *The risks and hazards of space flight must be presented to space flight participants "in a manner that can be readily understood by a space flight participant with no specialized education or training."*

  14 CFR 460.45, Operator Informing Space Flight Participant of Risk, 2013

- "*The FAA expects space flight participants to come from all walks of life, with varying degrees of technical expertise and understanding. Congress requires that a space flight participant be informed of the risks, not that he or she acquire an understanding of basic engineering principles in order to understand that risk.*" The operator may provide additional information, as necessary, if it helps to explain the risk.

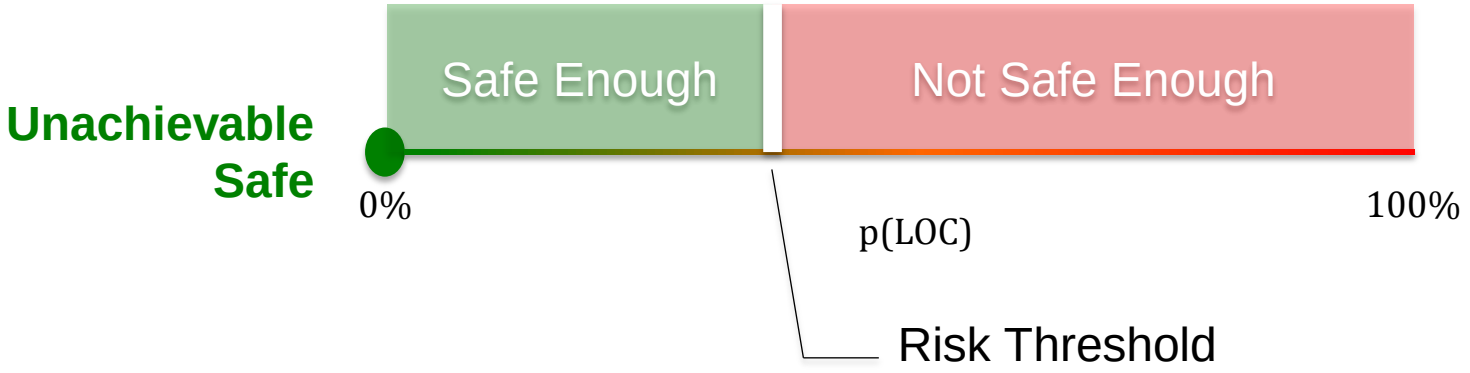
  FAA Guidance on Informing Crew and Space Flight Participants of Risk, Draft, Feb 17, 2016

- Recommended Practices for Human Space Flight Occupant Safety – Version 1.0, August 27, 2014, FAA, TC14-003
- FAA Environmental Control and Life Support Systems for Flight Crew and Space Flight Participants in Suborbital Space Flight, Version 1.0, April 2010

Results: Risk Assessment

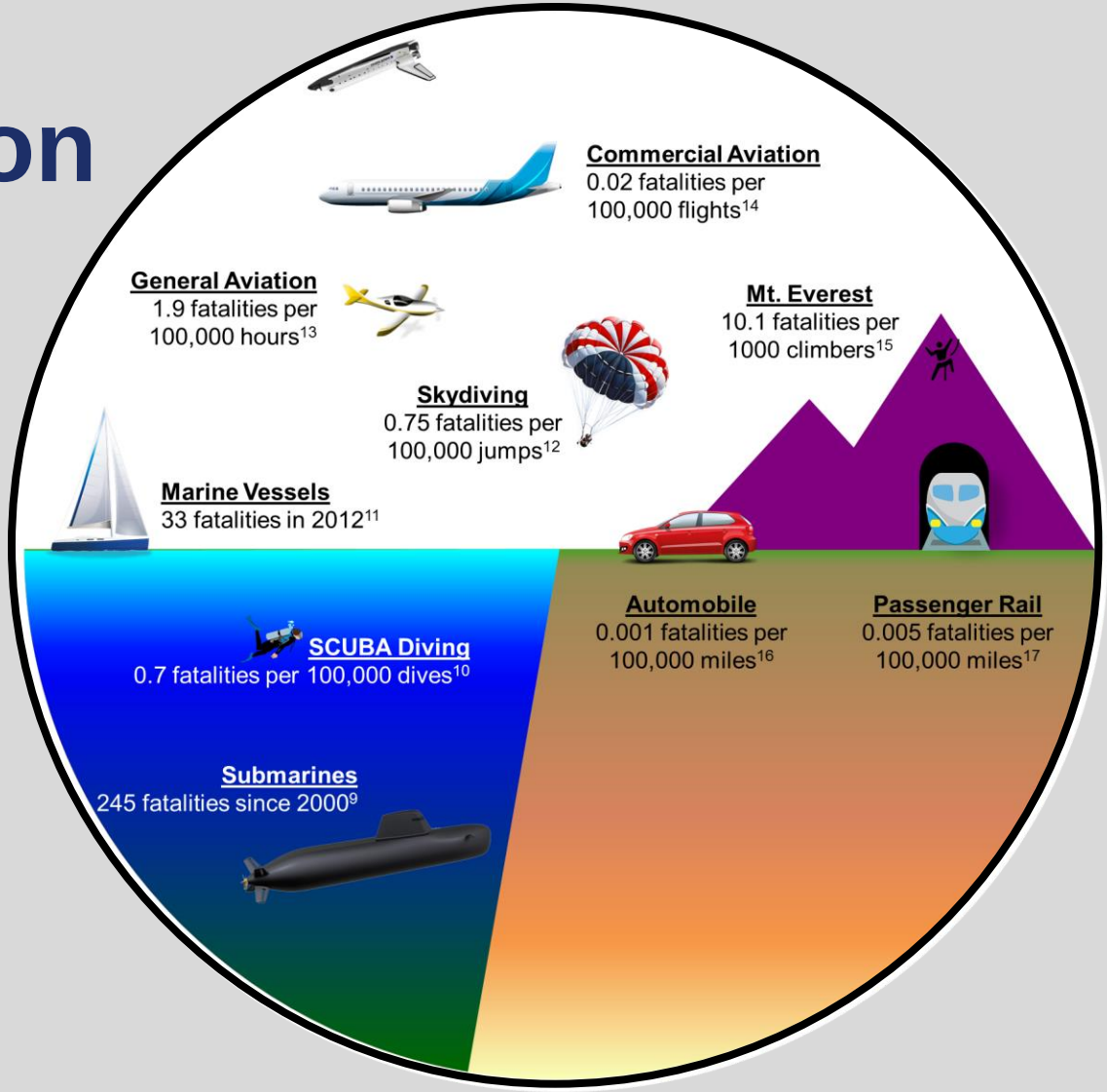
- **Safety** - *Freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment…"*
- **Safety Assurance** - *Providing confidence that acceptable risk for the safety of personnel, equipment, facilities, and the public during and from the performance of operations is being achieved.*

NPR 8715.3C (2008) NASA General Safety Program Requirements (w/Change 9 dated 2/08/13), *Washington DC*

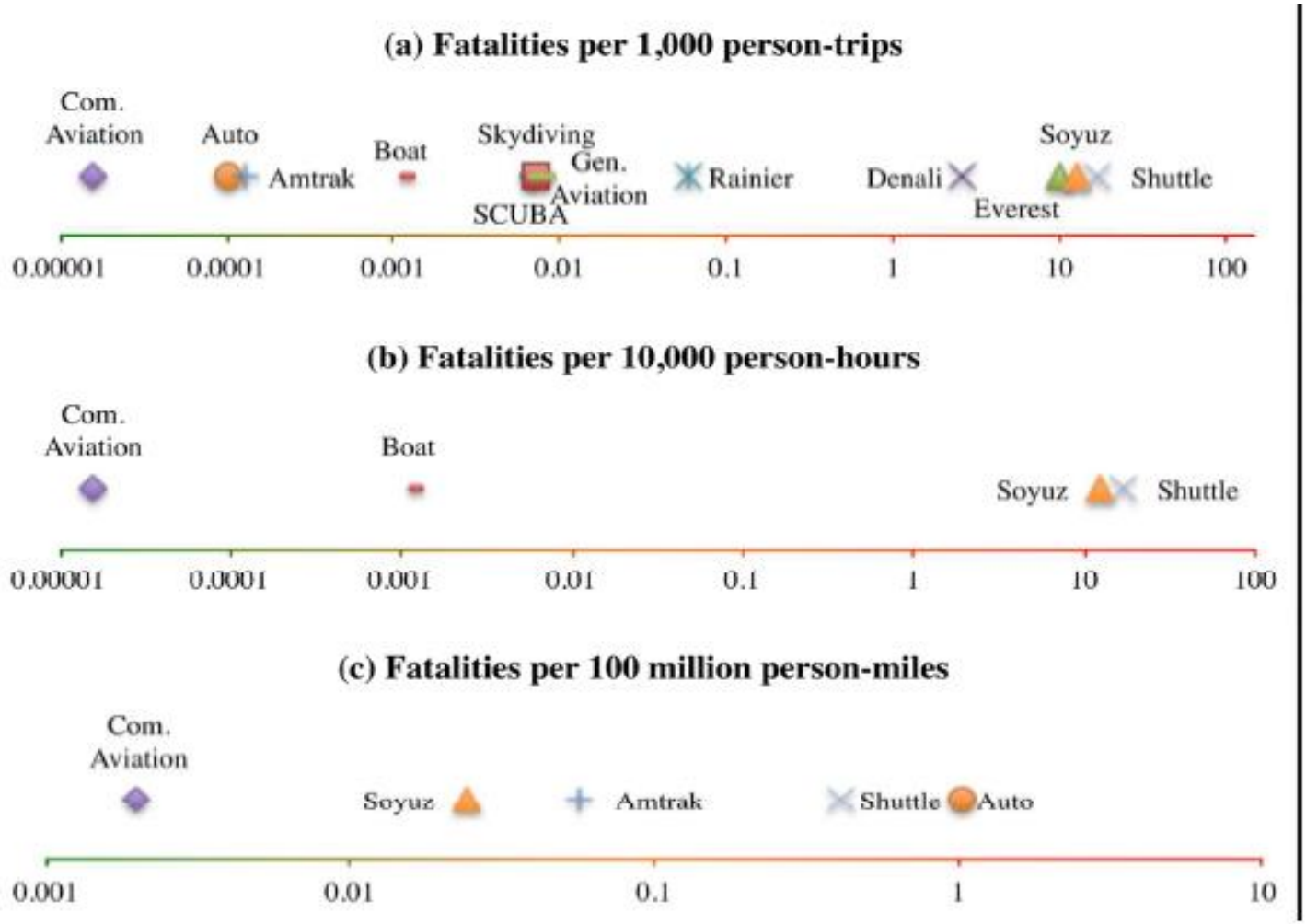


Ocampo and Klaus (2016a)

Results: Risk Communication

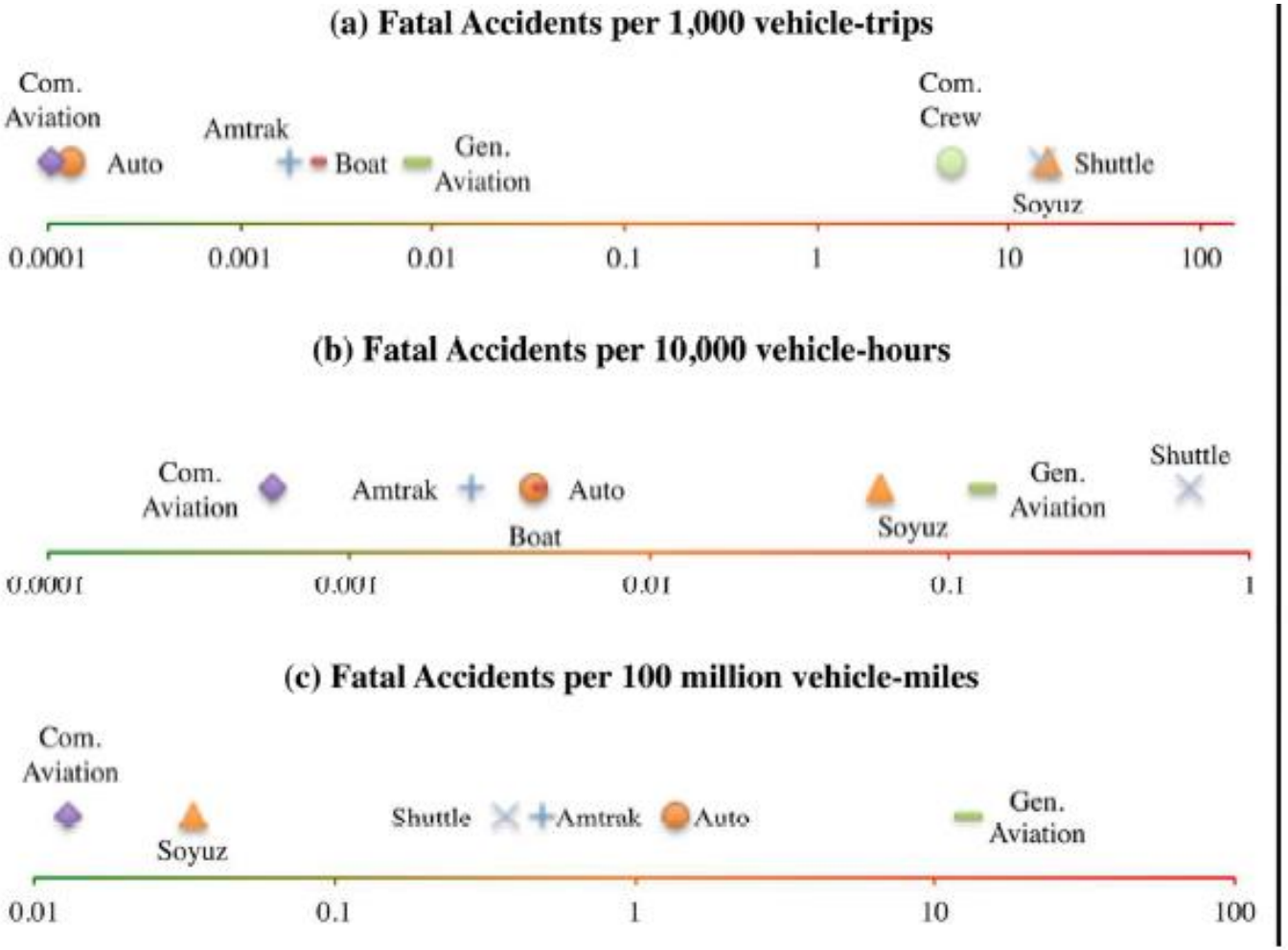


Results: person-centric



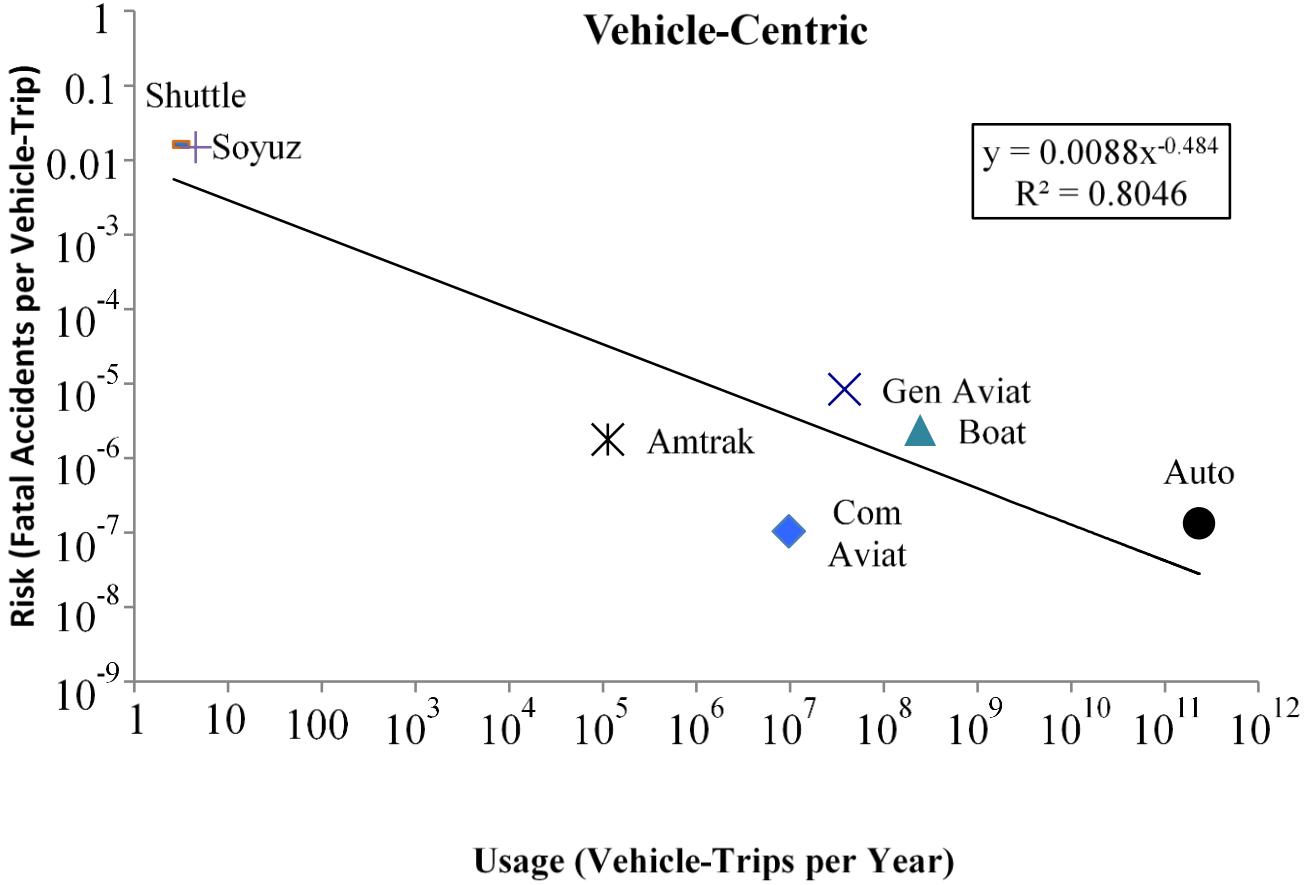
Ocampo, RP and Klaus, DM (2016b)

Results: vehicle-centric



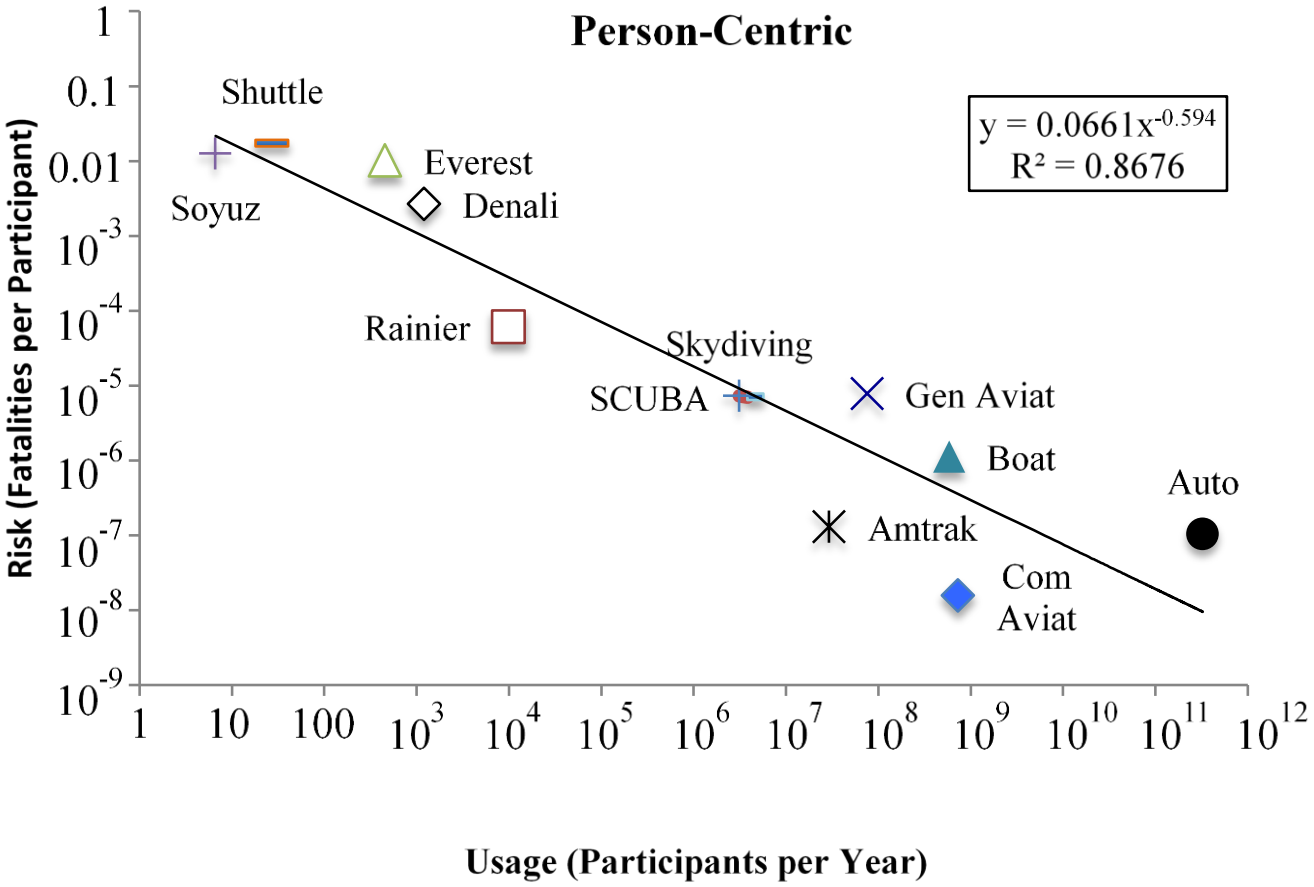
Ocampo, RP and Klaus, DM (2016b)

Results: vehicle-centric



Ocampo (2016)

Results: person-centric



Ocampo (2016)

Publications – Task 320 (2015-16)

- Ocampo, RP and Klaus, DM (2016e) Challenges in Determining 'Safe Enough' in Human Space Flight [in prep]
- Ocampo, RP and Klaus, DM (2016d) Adapting Pre-Hospital Emergency Medical Protocols for Commercial Space Flight [in prep]
- Ocampo, RP and Klaus, DM (2016c) A Heuristic Method for Predicting Risk in Human Space Flight. *J. Spacecraft and Rockets* [in review]

- Ocampo, RP and Klaus, DM (2016b) Comparing the Relative Risk of Space Flight to Terrestrial Modes of Transportation and Adventure Sport Activities. *New Space* [accepted]
- Ocampo, R. and Klaus, D. (2016a) A Quantitative Framework for Defining "How Safe is Safe Enough?" in Crewed Spacecraft. *New Space*, 4(2): 75-82. doi:10.1089/space.2015.0040
- Ocampo, R.P. (2016) Defining, Characterizing, and Establishing "Safe Enough" Risk Thresholds for Human Space Flight, *Doctoral Dissertation*, University of Colorado Boulder

Conclusions and Future Work

- **Task 320 Year 1 (June 1, 2015 through May 31, 2016)**
  - Delineated criteria defining ‘safe enough’
  - Unique perspective on risk provided by contrasting to more typical terrestrial transportation and adventure sport activities
  - Framework offered for scenario-dependent risk categorization and management strategies
- **Next Steps (June 1, 2016 through May 31, 2017)**
  - Assess and summarize recommended means of crew survivability to keep a ‘bad day’ from getting worse
  - Build on medical ‘levels of care’ to provide vehicle provisioning recommendations in conjunction with UTMB