Safety of Spaceflight Participants Aboard Suborbital Reusable Launch Vehicles – Background Research

Bob Seibold, Civil and Commercial Launch Projects, The Aerospace Corporation

Ronald Young, NASA Armstrong Flight Research Center (Retired)

Nickolas Demidovich, FAA Office of Commercial Space Transportation

Presentation to 10th IAASS Conference, 17 May 2019

Outline

1. Introduction
2. FAA and NASA Flight Participant Safety Practices
   - *Aviation*
   - *Astronauts*
   - *"Government Astronauts"*
   - *Soyuz*
3. Parametrically Projected Safety of Suborbital RLVs
4. FAA-AST Sponsored Study: Vehicle Guidelines for Safety-Critical Areas of sRLVs
5. FAA-AST Sponsored Study: Space Weather Biological and System Effects for Suborbital Flights
6. SFP Informed Consent
7. FAA-AST Compilation: U.S. Human Spaceflight Safety Record
8. Recommended Practices for Human Spaceflight Occupant Safety, FAA-AST
9. IAASS Space Safety Guidelines
10. Medical Assessment of Humans for Flight
    - *NASA Aviation Pilots and Space Astronauts*
    - *FAA Civil Aerospace Medical Institute (CAMI): Guidelines for Spaceflight Passengers*
    - *Aerospace Medical Association: Recommendations for Spaceflight Crewmembers*
11. Spaceflight Participant Training
12. ASTM-International Committee F47 on Commercial Spaceflight
13. Comparison with Another Challenging Environment: Deep Sea Submersibles
14. Sources for Further Reading

1. Introduction

- Anticipated advent of U.S. Government sponsoring human-tended research and human medical studies on commercial suborbital flights necessitates establishment of safety review procedures for federal agencies to allow government-sponsored SFPs aboard these vehicles.
- Three Payload Categories:
  - *Stand-alone*
  - *Tended by crew member employed by flight provider*
  - *Interactive / interpreted payloads requiring tending by investigator*
- U.S. Congress encouraging emergence of commercial space capabilities by limiting government regulatory requirements:
  - *Commercial sRLV providers are licensed under FAA-AST regulations to assure safety of the uninvolved public under a designated "learning period."*
  - *FAA-AST has developed and published recommended practices for human spaceflight occupant safety and training, discussed later, to serve as guidelines for developers during this learning period. These recommended practices are intended to be translated into a regulatory safety certification regime after the learning period expires.*
  - *SFPs are informed that the vehicle has not been independently certified as safe by the FAA. They are informed of specific risks and must sign a waiver of liability based on informed consent.*

2A. FAA and NASA Flight Participant Safety Practices

- Aviation
  - *FAA has established and modified rules over decades to ensure passenger safety*
    - Proven maintenance standards and practices based on practical experiences
    - Rigorous aircrew training standards and requirements
  - *NASA's aviation safety authority pre-dates FAA and self-regulates NASA-sponsored personnel aboard public-use and non-NASA-controlled aircraft*
- Astronauts
  - *(NPR) 8705.2C*: Establishes procedural and technical requirements for human-rating certification. Exceptions are the ISS and Soyuz (and in an earlier revision, the Space Shuttle), which are not required to obtain a human-rating certification. Those programs "utilize existing policies, procedures, and requirements to certify their systems for NASA missions."*
- "Government Astronauts"
  - *Space Act of 2015** created new category of NASA people flying on commercial rockets, viz., "Government Astronauts"*
  - *Allows highly trained astronauts to perform operations not allowed for SFPs*
  - *NASA Administrator identifies which flight occupants are so designated*

*Human-Rating Requirements for Space Flight Systems, NASA Procedural Requirements (NPR) 8705.2C: https://nodis3.gsfc.nasa.gov/npg_img/N_PR_8705_002C_/N_PR_8705_002C_.pdf

**H.R.2262 - U.S. Commercial Space Launch Competitiveness Act

2B. FAA and NASA Flight Participant Safety Practices – Soyuz

Multiple solutions along "arc of acceptability" have proven successful:

Reference: "NASA Astronauts on *Soyuz*: Experience and Lessons for the Future," prepared by Office of Safety and Mission Assurance (OSMA) Assessments Team, Johnson Space Center, Houston, NASA/SP-2010-578, Aug 2010. https://spaceflight.nasa.gov/outreach/SignificantIncidents/assets/nasa-astronauts-on-soyuz.pdf

3A. Parametrically Projected Safety of Suborbital RLVs

- Goal: Develop a model for predicting safety of new rocket-powered sRLVs
- Approach: Evaluate effects of vehicle catastrophic failure on the vehicle provider's business case, focusing on demand vs. supply. This market focus emphasized "probability of failure" as opposed to more conventional reliability modeling approaches based on "probability of success."
- Primary Challenge: To bridge performance data and cultural differences across several distinct areas with scant data:
  1. Subsonic, supersonic, and orbital flight
  2. Expendable and reusable vehicles, human-rated and non-human-rated
  3. Old and new technologies
  4. Past vs. present concepts of safety (user and government culture)
  5. Vehicle end use (commercial, recreational, government, military)
  6. Differences in vehicle test programs (minimal versus extensive)
- Parametric Approach: The predictions were based upon 2015 flight technology, Mach 3.5 maximum speed, professionally piloted human-rated systems, FAA controlled airspace/flight rules, FAA safety regulations, and flight profile and other variables, all programmed into the model.
- Result: Safety comparison of a specific sRLV against other flight vehicle categories and activities. Safety of examined RLV was found to range across columns C and D on next slide.
- Conclusions: The developed model can be a useful tool for comparing candidates to historical systems and constructing a Business Case Analysis for newly developed flight vehicles. The model responds to changes in parameters deemed important to flight safety and is calibrated to relevant history.

Reference: Webb, D. W., G. S. Williams, A. Q. Tu, R. W. Seibold, C. E. Baker, and R. M. Young, "Market Demand Methodology for U.S. Suborbital Reusable Launch Vehicle Industry," *AIAA Space 2014 Conference and Exposition,* San Diego, CA, AIAA paper 2014-4201, August 4-7, 2014.

AEROSPACE

3B. Probability of Catastrophic Failure for Flight Vehicles and from Other Activities

A: Expected ($Pr > 10^{-1}$)	B: Probable ($10^{-1} \geq Pr > 10^{-2}$)	C: Likely ($10^{-2} \geq Pr > 10^{-3}$)	D: Unlikely ($10^{-3} \geq Pr > 10^{-6}$)	E: Improbable ($Pr \geq 10^{-6}$)
• **New ELVs** (first 10 launches) • U.S. Civil War (Union) • WWII U-Boat • High-Altitude Mountaineering	• **Orbital Launch** (All vehicles) • **STS** • **XB-70** • Normandy (D-Day) • Grand Prix Racing • Base Jumping	• **X-15** • Hang Gliding • Motorbike Racing	• **Concorde** • Automobiles • Skydiving • Bungee Jumping • Swimming • Fire	• **General Aviation** • Skiing • Lightning Strike

Safety of examined RLV was found to range across columns C and D.

1. Webb, D. W., G. S. Williams, A. Q. Tu, R. W. Seibold, C. E. Baker, and R. M. Young, "Market Demand Methodology for U.S. Suborbital Reusable Launch Vehicle Industry," *AIAA Space 2014 Conference and Exposition,* San Diego, CA, AIAA paper 2014-4201, August 4-7, 2014.
2. Global Fatal Accident Review, 2002 to 2011, CAP 1036, U.K. Civil Aviation Authority, June 2013. https://publicapps.caa.co.uk/docs/33/CAP%201036%20Global%20Fatal%20Accident%20Review%202002%20to%202011.pdf

4. FAA-AST Sponsored Study: Vehicle Guidelines for Safety-Critical Areas of sRLVs

The Aerospace Corporation was tasked by FAA-AST in 2002-2003 to develop minimum vehicle guidelines for safety-critical areas of commercial RLVs, necessary to ensure the safety of flight crew and passengers. This study informed development of FAA recommended practices for human spaceflight safety (discussed later in Section 8).

- The guidelines were developed by reviewing and analyzing specifications, requirements, and lessons-learned for safety of commercial, military, and experimental aircraft, military space systems, and past and present human-carrying space systems, followed by interpolation and projection of these requirements for crew and passengers aboard both suborbital and orbital categories of future commercial RLVs.
- Subsystems evaluated:
  - *environmental control and life support system*
  - *main propulsion system*
  - *guidance, navigation, and control system*
  - *avionics and software*
  - *main structural system*
  - *thermal protection system*
  - *thermal control system*
  - *health monitoring system*
  - *electrical power system*
  - *mechanical systems*
  - *flight safety system*
  - *crew system*

Reference: Patel, N. R., J.C. Martin, R. J. Francis, and R. W. Seibold, “Human Flight Safety Guidelines for Reusable Launch Vehicles,” Final Report, U.S. Department of Transportation Contract DTRS57-99-D-00062, Tasks 2 and 3, Aerospace Corporation Report ATR-2003(5050)-1, July 31, 2003.

5. FAA-AST Sponsored Study: Space Weather Biological and System Effects for Suborbital Flights

Objectives:

- Identify and describe typical dose rates and expected radiation hazards to crew and SFPs on suborbital flights from low, middle, and high latitudes, including effects of solar cycle and extreme solar and geomagnetic events.
- Based on the hazards identified, determine mitigation measures and safe phenomena threshold levels. Determine recommended flight rules to minimize space weather hazards based on results of the mitigation methods.

Conclusions:

- Owing to the short duration of flights (~30 min. or less) and the even shorter exposure at altitudes where atmospheric shielding is significantly reduced (~ 5 min.), exposure of crew and passengers is minimal, except under circumstances where solar particle events (SPEs) occur, which is less than about 5% of the time. Under typical conditions, the radiation exposure to crew and passengers on a suborbital flight is less than that for a long duration airline flight.
- Avoiding exposure to potentially harmful radiation associated with solar or geophysical disturbances can be achieved by locating launch sites at middle latitudes, or lower, or by delaying flights when there are indications that an SPE is in progress or is imminent. For a high-latitude site, a possible launch commit criterion could be based on event probability distributions.

Reference: Turner, R. E., T. A. Farrier, J. E. Mazur, R. L. Walterscheid, and R.W. Seibold, "Space Weather Biological and System Effects for Suborbital Flights," Final Report, U. S. Department of Transportation Contract DTRT57-05-D-30103, Task 13B, Aerospace Corporation Report No. ATR-2009(5390)-1, October 31, 2008.
http://www.faa.gov/about/office_org/headquarters_offices/ast/reports_studies/media/ATR-2009(5390)-1.pdf

6. SFP Informed Consent

Legislation:

- Commercial Space Launch Amendments Act (CSLAA), 2004
- U.S. Commercial Space Launch Competitiveness Act, 2015

Legislation gives FAA-AST authority to regulate commercial space flight but does not allow the FAA to regulate the safety of people aboard space vehicles. Instead, the law requires informed consent of onboard crew and passengers. The occupants must state in writing that they (1) understand that the U.S. Government has not certified the space launch or reentry vehicle as safe and (2) be informed of the risks of the vehicle they are boarding and others like it.

Reference: Nield, G. C., N. Johnson, J. Duffy, and J. Sloan, "Informed Consent in Commercial Space Transportation Safety," IAC-13-D5.1.4, Sept 2013. https://www.faa.gov/about/office_org/headquarters_offices/ast/programs/international_affairs/media/Informed_Consent_paper_IAC_Sept_2013_FAAfinal.pdf

Waiver of liability and informed consent are two different things.
U.S. Government civil servants cannot grant liability waivers.

7A. FAA-AST Compilation: U.S. Human Space Flight Safety Record

Launch Type	Total # of People on Space Flight	Total # People Died or Seriously Injured[3]	Total # of Human Space Flights	Total # of Catastrophic Failures[6]
Orbital (Total)	921[1]	17	164[4]	3
Suborbital (Total)	208[2]	3	204[5]	2
Total	1129	20	368	5

- **§ 460.45(c).** An operator must inform each space flight participant of the safety record of all launch or reentry vehicles that have carried one or more persons on board, including both U.S. government and private sector vehicles. This information must include—

  (1) The total number of people who have been on a suborbital or orbital space flight and the total number of people who have died or been seriously injured on these flights; and

  (2) The total number of launches and reentries conducted with people on board and the number of catastrophic failures of those launches and reentries.

Compiled by FAA-AST, October 2017.
https://www.faa.gov/about/office_org/headquarters_offices/ast/regulations/media/HSF_Safety_Record_Data_with_footnotes_Final.pdf

NASA AEROSPACE

7B. Footnotes from Previous Chart

1. People on orbital space flights include Mercury (Atlas) (4), Gemini (20), Apollo (36), Skylab (9) and Space Shuttle (852)
   a) Occupants are counted even if they flew on only the launch or reentry portion. The Space Shuttle launched 817 humans and picked up 35 humans from MIR and the International Space Station
2. People on suborbital space flights include include X-15 (169), M2 (24), Mercury (Redstone) (2), SpaceShipOne (5) and SpaceShipTwo (8)
   a. Only occupants on the rocket-powered space bound vehicles are counted per safety record criterion #11
3. Deaths and serious injuries include X-15 (1), Apollo-Soyuz Test Project (3), Challenger (7), Columbia (7) and SpaceShipTwo (2)
   a) Deaths or serious injuries that occurred when there was no intent to launch (e.g. Apollo 1 fire), are not counted per safety record criterion #9
   b) Alan Bean during splashdown on Apollo 12 suffered a concussion. The FAA uses the NTSB's definition of serious injury (criterion #13), but the NTSB does not consider a concussion itself a serious injury. The FAA will remain consistent with the NTSB and not count this incident as a serious injury
4. Orbital flights include Mercury (Atlas) (4), Gemini (10), Apollo (12), Skylab (3) and Space Shuttle (135)
5. Suborbital flights include X-15 (169), M2 (24), Mercury (Redstone) (2), SpaceShipOne (5) and SpaceShipTwo (4)
   a) Glide flights are not counted per safety record criterion #2
   b) Flights that fail to meet the definition of suborbital rocket in 14 CFR § 401.5 are not counted (thrust must be greater than lift) e.g. some X-15 and M2 flights
6. X-15 Flight 191, Challenger STS-51-L, Columbia STS-107, SpaceShipTwo VSS Enterprise, Apollo-Soyuz Test Project

8A. Recommended Practices for Human Space Flight Occupant Safety – FAA-AST

After working closely with NASA, industry, and other key stakeholders, FAA-AST issued its “Recommended Practices for Human Space Flight Occupant Safety.” This document was the culmination of a 3-year effort, which involved researching existing human spaceflight standards, conducting a series of public teleconferences to gather recommendations, and soliciting feedback from the Commercial Space Transportation Advisory Committee (COMSTAC).

“Recommended Practices for Human Space Flight Occupant Safety,” Version 1.0, FAA Office of Commercial Space Transportation, August 27, 2014.
https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Recommended_Practices_for_HSF_Occupant_Safety-Version_1-TC14-0037.pdf

All U.S. commercial sRLV flights are licensed and regulated by FAA-AST. However, FAA-AST does not certify the vehicles or regulate safety of crew or SFPs.

AEROSPACE

8B. Recommended Practices for Human Space Flight Occupant Safety – FAA-AST

<u>Approach</u>:

- FAA reviewed existing government and private sector requirements and standards
- Chose to primarily use NASA's requirements and guidance for Commercial Crew Program (1100 Series) as a guide.
  - *Purpose was not to copy NASA's requirements, but to use them as a means to capture relevant safety concepts.*
- Consulted with:
  - *Commercial Space Transportation Advisory Committee (COMSTAC)*
  - *FAA Civil Aerospace Medical Institute (CAMI)*
  - *FAA Center of Excellence for Commercial Space Transportation*
  - *NASA: Meeting held November 12, 2013.*

8C. Recommended Practices for Human Space Flight Occupant Safety – FAA-AST

Scope:

- Occupant safety only
  - *Public safety and mission assurance not directly addressed*
  - *Orbital and suborbital flights*
- Orbital rendezvous and docking, long duration flights, extravehicular activity, and flights beyond earth orbit not explicitly covered
- Period of coverage – from when occupants are exposed to vehicle hazards prior to flight through when they are no longer exposed to vehicle hazards after landing

Safety Level:

- No specific level of safety (risk) due to wide variety of systems and flight profiles likely in the near future
- Two levels of care articulated:
  - *Occupants should not experience an environment during flight that would cause death or serious injury (a low bar)*
  - *Level of care for flight crew when performing safety critical operations is increased to level necessary to perform those operations*

  In an emergency the same level of care is not expected to be maintained – only a reasonable chance of survival

8D. Recommended Practices for Human Space Flight Occupant Safety – FAA-AST

<u>Assumptions</u>:

- Covers suborbital and orbital launch and reentry vehicles
  - *Orbital vehicles*
    - Stay on orbit for 2 weeks maximum
    - Can return to earth in under 24 hours if necessary
- Each flight crew member is safety-critical
- SFPs may be called upon to perform limited safety-critical tasks
- Clean sheet philosophy – no other regulations act to protect occupants from harm

<u>Notable Omissions</u>:

- Medical limits for SFPs
  - *Medical consultation recommended*
  - *SFPs free to assess their individual risk*
- Ionizing radiation
  - *Long-term health issues not addressed*
- Integration of occupant and public safety
  - *Area for future FAA-AST work*

8E. Recommended Practices for Human Space Flight Occupant Safety – FAA-AST

Recommended Practices Covered:

- Design
  - *Human Needs and Accommodations*
  - *Human Protection*
  - *Flightworthiness*
  - *Human/Vehicle Integration*
  - *System Safety*
  - *Design Documentation*
- Manufacturing
- Operations
  - *Management*
  - *System Safety*
  - *Planning, Procedures, and Rules*
  - *Medical Considerations*
  - *Training*

9. IAASS Space Safety Guidelines

- In March 2010, the IAASS issued Space Safety Standard IAASS-ISSB-S-1700-Rev-B, "Commercial Human-Rated System. The requirements in this document were established on the basis of the safety experience accumulated in human spaceflight to date.
- In December 2013, the IAASS issued guidelines for the safe regulation, design, and operation of suborbital vehicles.*
- Recently SAE International and IAASS co-published a standard, IAASS-SSI-1700, "Commercial Human-Rated System," as a step towards the establishment of a complete set of safety, technical, and management standards to be used by industry for the design and development of commercial space systems, and by an independent third-party, the Space Safety Institute, for their certification.

*Guidelines for the Safe Regulation, Design and Operation of Suborbital Vehicles, Manual, International Association for the Advancement of Space Safety (IAASS), Suborbital Safety Technical Committee, Dec 2013. https://www.faa.gov/about/office_org/headquarters_offices/ast/advisory_committee/meeting_news/media/2014/may/15_IAASSSuborbitalSafetyGuidelinesManual_Dec2013_Master.pdf

10A. Medical Assessment of Humans for Flight

Bendrick, G. A.,* Chief Medical Officer, NASA-Armstrong Flight Research Center, "Assessing the Human for Flight," NASA Engineering and Safety Center (NESC) Academy, June 13, 2017:

- Medical assessment of pilots and astronauts to ensure they are medically qualified for flight duties
- Medical examiner acts on behalf of the regulatory agency to help ensure safety of flight:
  - *The performance of specific examination REQUIREMENTS,*
  - *Identifying whether or not the individual meets specified STANDARDS, and if not;*
  - *Determining the appropriate WAIVER questions or concerns that must be satisfactorily addressed before a safe return to flight can be implemented.*
- The 1% rule
  - *Denies medical certificate to airline pilot if their risk of a medical incapacitation (e.g., heart attack, convulsion, stroke, fainting, etc.) is determined to be greater than 1% per annum*
- Medical surveillance

*Present address: FAA Civil Aerospace Medical Institute (CAMI), Oklahoma City

10B. Medical Screening of Commercial Aerospace Passengers

- CAMI report* provides general guidance for operators of manned commercial aerospace flights (suborbital and orbital) in the medical assessment of prospective passengers:
  - *Categories of Passengers:*
    - Passengers participating in suborbital aerospace flights (or exposed to G-load of up to +3Gz during any phase of the flight)
    - Passengers participating in orbital aerospace flights (or exposed to G-load exceeding +3Gz during any phase of the flight)
  - *Discusses acceleration risks associated with the neurological, cardiovascular, and musculoskeletal systems*
  - *Discusses medical conditions that may contra-indicate passenger participation in suborbital or orbital flights and disposition of prospective passengers with these conditions*
- These medical considerations were considered in FAA-AST's "Recommended Practices for Human Space Flight Occupant Safety"

*Antuñano, M. J., et al., "Guidance for Medical Screening of Commercial Aerospace Passengers," FAA Civil Aerospace Medical Institute (CAMI), Final Report, DOT/FAA/AM-06/1, Jan 2006: https://ntl.bts.gov/lib/39000/39900/39957/200601.pdf

AEROSPACE

10C. Medical Recommendations for Operationally Critical Flight Crewmembers

Proposed recommendations for operationally critical flight crewmembers participating in suborbital spaceflight:*

- An FAA first-class medical certificate using same age-based schedule as for Airline Transport Pilot (ATP) pilots
- Pre-flight medical evaluation
- Post-flight medical debrief with data collection
- An independent data repository of medical findings
- Periodic reevaluation of the current medical standards during the early stages of developmental flights
- Passive ionizing radiation dosimeters worn by each flight crewmember
- Auditory protection in the helmet or headset for all crewmembers
- Emergency egress training for all crewmembers
- Physiologic training (altitude chamber) to ensure flight crew recognition of signs and symptoms associated with decompression, including hypoxic changes
- Recent centrifuge or other G training
- Anti-G suit use on flights until more experience has been obtained
- Parabolic flight training
- Pressure suit use for commercial spaceflight operators
- Further investigation on effects on pilot performance from rapid changes in the acceleration/ microgravity/entry deceleration flight profile

*"Suborbital Commercial Spaceflight Crewmember Medical Issues," Position Paper, Aerospace Medical Association Commercial Spaceflight Working Group, *Aviation, Space, and Environmental Medicine*, vol. 82, no. 4, Apr 2011, pp. 475-484. http://spacemedicineassociation.org/download/executive_archive_files/s11.pdf

11. Spaceflight Participant Training

Three SFP training centers approved by FAA-AST:

- National AeroSpace Training and Research (NASTAR) Center, Southampton, PA
  - *http://www.nastarcenter.com/aerospace-training/space/passengers*
  - *FAA Safety Approval No's. SA 10-001, SA 12-004*
  - *Basic Suborbital Space Training, Advanced Space Training, Space Payload Specialist Training, Space Suits and Systems Training*
- Black Sky Training, Colorado City, TX
  - *https://blacksky.aero/*
  - *FAA Safety Approval No's. SA 13-005, SA 14-006*
  - *Crew & Spaceflight Participant Training, Scenario-Based Physiology Training*
- Waypoint 2 Space, Houston, TX
  - *http://www.waypoint2space.com/*
  - *FAA Safety Approval No. SA 14-007*
  - *Level 1 Overview Training, Level 2 Suborbital Space Environment Training. Level 3 Orbital Training Program scheduled to begin in 2020.*

12. ASTM International Committee F47 on Commercial Spaceflight*

- Committee F47 formed 2016
- Industry utilizing ASTM's neutral forum to develop safety and quality standards and recommended practices to facilitate positioning for future regulatory requirements as well as innovation in this progressing area.
- Nine technical subcommittees develop and maintain voluntary consensus standards. Two are addressing human spaceflight safety:
  - *F47.01, Occupant Safety of Suborbital Vehicles*
    - Developing new Guide, "Fault Tolerance for Occupant Safety of Suborbital Vehicles"
  - *F47.02, Occupant Safety of Orbital Vehicles*

https://www.astm.org/COMMITTEE/F47.htm

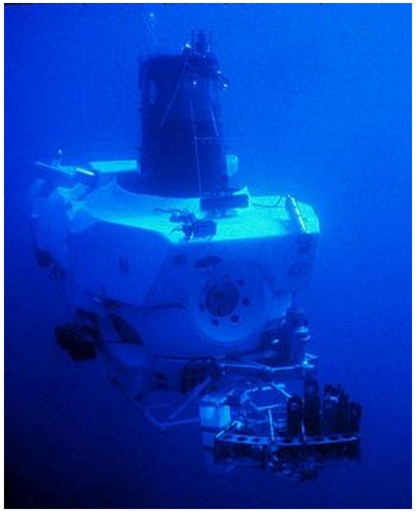
*Formerly American Society for Testing and Materials

13A. Comparison with Another Challenging Environment: Deep Sea Submersibles

Deep Sea Submersibles - Overview

- Representative active submersibles, each owned by a national government:
  - *U.S.: DSV-2 Alvin, to 4,500 m., owned by U.S. Office of Naval Research (ONR), operated by Woods Hole Oceanographic Institution (WHOI)*
  - *Australia: Deepsea Challenger (DCV 1), carried Titanic director, James Cameron, to ocean's deepest point, Challenger Deep, >10,900 m.*
  - *France: Nautile, to 6,000 m.*
  - *Japan: Shinkai, to 6,500 m.*
  - *China: Jiaolong, to 7,500 m.*

Alvin

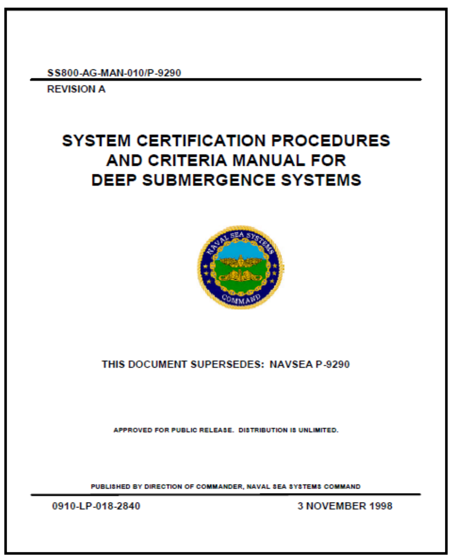


- In development, commercial company:
  - *U.S., OceanGate, Inc.: Cyclops 2, to >4,000 m., multi-person, carbon composite hull*

13B. Human Safety in Deep Sea Submersibles

Human safety in submersibles is assured via a detailed systems certification approach:

- For example, safety of *Alvin* is controlled by a 350-page NAVSEA manual* specifying detailed certification procedures for materials and components, design factors, testing parameters, life support systems, airborne contaminants, and much more.
- The USG does not yet require that type of certification for sRLVs. FAA-AST's role regarding sRLV safety is limited to licensing and regulating until a later date when the industry is mature.



SS800-AG-MAN-010/P-9290
REVISION A

SYSTEM CERTIFICATION PROCEDURES
AND CRITERIA MANUAL FOR
DEEP SUBMERGENCE SYSTEMS

THIS DOCUMENT SUPERSEDES: NAVSEA P-9290

APPROVED FOR PUBLIC RELEASE. DISTRIBUTION IS UNLIMITED.

PUBLISHED BY DIRECTION OF COMMANDER, NAVAL SEA SYSTEMS COMMAND

0910-LP-018-2840 3 NOVEMBER 1998

*Naval Sea Systems Command, System and Certification Procedures Criteria Manual for Deep Submergence Systems, SS800-AG-MAN-010/P9290, Rev. A, Nov 3, 1998.

14. Sources for Further Reading

1. Roberts, M. A., “Legal Considerations for Flying Astronauts on Commercial Space Vehicles,” IAC-16-B3.2.2., *67th International Astronautical Congress (IAC 2016),* 26-30 September 2016, Guadalajara, Mexico.
2. Leung, R., S. Sarai, and T. Mazzuchi, “Mission Success Regulations, Their Effect on ELV Launch Success and the Applicability to Regulating Commercial Human Spaceflight,” *Space Policy*, v. 29, issue 4, Nov 2013, 258-265.
3. Bouchey, M. and J. Delborne, “Redefining Safety in Commercial Space: Understanding Debates over the Safety of Private Human Spaceflight Initiatives in the United States,” *Space Policy*, v. 30, issue 2, May 2014, pp. 53-61.
4. Seibold, R. W., J. A. Vedda, J. P. Penn, G. W. Law, J. M. Logsdon, J. A. Hoffman, et al., “Analysis of Human Space Flight Safety – Report to Congress,” Final Report, FAA Contract DTFAWA-07-C-00084, Aerospace Corporation Report No. ATR 2009(5397)-1, Nov 11, 2008. https://www.faa.gov/about/office_org/headquarters_offices/ast/media/Human%20Spaceflight%20Safety%20Report_11Nov08.pdf