COE CST Third Annual Technical Meeting (ATM3)

Task 184
Human-Rating of Commercial Spacecraft

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Center of Excellence for Commercial Space Transportation

Overview

- Team Members
- Purpose of Task
- Research Methodology
- Results or Schedule & Milestones
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- Contact Information

Team Members

- **David Klaus**, PI, University of Colorado Boulder
- **Christine Fanchiang**, PhD student, CU Aerospace (funded by COE)
- **Robert Ocampo**, PhD student, CU Aerospace (funded by SNC)
- **Henry Lampazzi, Jeff Sugar, Randy Repcheck**, (*Pam Melroy, Rene Rey*) FAA
- **Human-rating Working Group Participants**
  - Armadillo Aerospace
  - Boeing
  - Sierra Nevada Corporation
  - SpaceX
  - United Launch Alliance (ULA)
  - Draper Laboratory
  - Environmental Tectonics Corporation (ETC)-NASTAR Center
  - Metropolitan State College of Denver
  - Space Adventures
  - University of Texas Medical Branch (UTMB)
  - Wyle
  - Baylor
  - University of Colorado (Law)
  - University of Nebraska (Law)

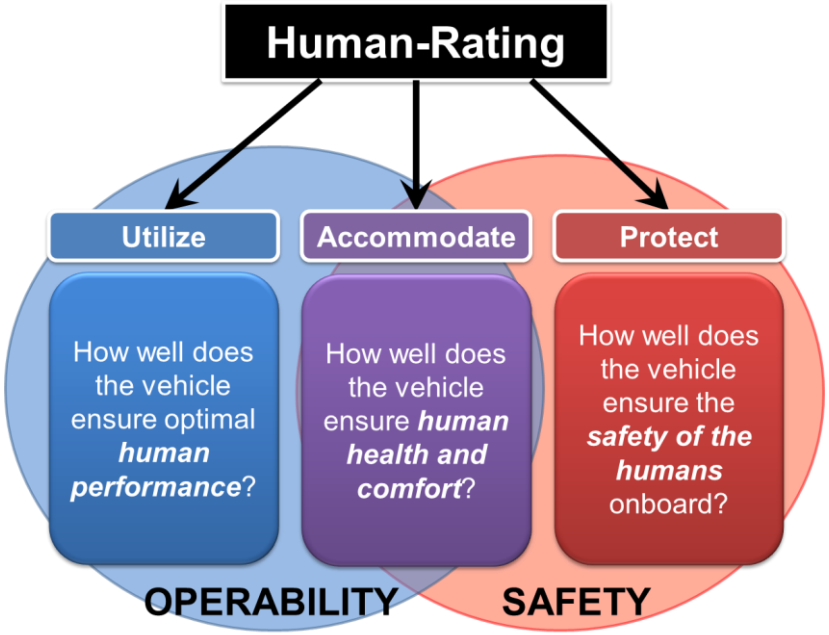
Purpose of Task

- Purpose
- The purpose of this task is to *define* and *assess* appropriate *criteria and protocols* for human-rating of commercial spacecraft to support development of certification needs and verification methods.
- Objectives - *year 3* (6/1/13 to 5/31/14)
- Establish Industry-wide Consensus on Key Terms and Definitions
- Analyze Considerations for Safety/Risk Classification
- Review and Support 'FAA Established Practices for Human Spaceflight Occupant Safety' (draft)
- Goals
- Develop report on 'Human-Rating Guidelines and Considerations for Commercial Space Transportation' addressing requirements, validation & verification, and regulatory practices

Research Methodology

What is Human-Rating?

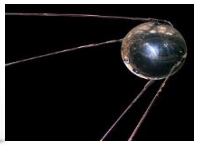
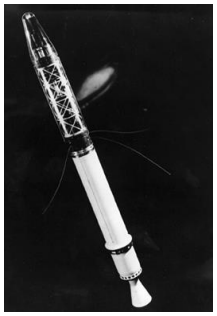
"A human-rated system ***accommodates*** human needs, effectively ***utilizes*** human capabilities, controls hazards and ***manages safety*** risk associated with human spaceflight, and provides, to the maximum extent practical, the capability to safely recover the crew from hazardous situations.



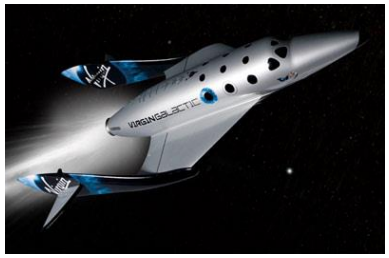
NASA NPR 8705.2B. Human-Rating Requirements for Space Systems, 2012

Current research is focused on safety considerations for the spacecraft occupants & uninvolved public.

Human-Rating Perspectives

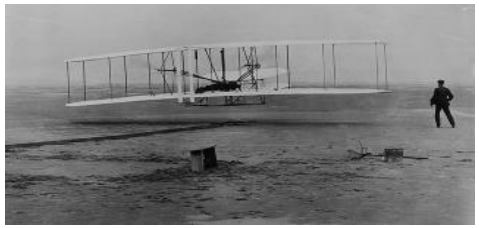




UNMANNED **ASTRONAUTICS** ***MANNED***

~100 years

MANNED **AERONAUTICS** ***UNMANNED***




Review of 'Man/Human-Rating' Practices

- **X-Series (1940s-1950s)**
  - First reference found to 'man-rated' system
  - X-15 capable of suborbital spaceflight
- **Mercury (1961-1963) and Gemini (1965-1966)**
  - Redundancy, conservative design, reliability, and abort systems
- **Apollo (1968-1975)**
  - Extensive ground and flight tests
  - First launch vehicle specifically designed for humans
- **Skylab (1973-1974)**
  - Man-rating extended from just safety to include operability
- **Space Shuttle (1981-2011)**
  - First launch vehicle not tested in unmanned configuration

Review of 'Man/Human-Rating' Documents

- **NASA 410-24-13-1** Launch Vehicle Man-Rating, 1963
- **NHB 5300.4 (1D-2)** Safety, Reliability, Maintainability and Quality Provisions for the Space Shuttle Program, October, 1979
- **JSC-23211** Guidelines for Man Rating Space Systems, 1988
- **NASA SP 6104 A** Perspective on the Human-Rating Process of U.S. Spacecraft: Both Past and Present, 1995
- **NASA NPG 8705.2** Human-Rating Requirements and Guidelines for Space Flight Systems, 2003-2008
- **NASA NPR 8705.2A** Human-Rating Requirements for Space Systems, 2005-2010
- **NASA NPR 8705.2B** Human-Rating Requirements for Space Systems, 2008-2013
- **NASA CCT-1001** Commercial Human-Rating Plan (Draft), May 21, 2010

NASA Commercial Crew References

- **CCT-REQ-1130** *International Space Station (ISS) Crew Transportation Certification and Services Requirements Document*
  - NASA ISS crew transport certification and service requirements
- **CCT-STD-1140** *Commercial Crew Transportation Evaluation of Technical Standards*.
  - technical, safety, and crew health & medical processes
- **CCT-PLN-1100** *Commercial Crew Transportation Plan*
  - certification to transport NASA/NASA-sponsored crew members
- **CCT-DRM-1110** *Commercial Crew Transportation System Design Goals*\
  - reference missions to transport humans to/from ISS & LEO destinations
- **CCT-STD-1150** *Commercial Crew Transportation Operations Standards*..
  - establishes the ground and flight operations processes
- **NASA SSP-50808** ISS to COTS Interface Requirements Document
- **AFSPCMAN-91-710** Range Safety User Requirements

Evaluating Safety / Risk

1) Assessing Risk –varying methods focus on quantification

Severity	Consequence
1	No Impact / Monitor
2	Degraded Performance
3	Loss of Mission (LOM)
4	Loss of Vehicle (LOV)
5	Loss of Crew (LOC)

Risk management process

1) Identify hazards.
2) Define the consequence if hazard is realized.
3) Assess the probability of realizing hazard.

Typical risk outcome assessment scheme

2) Accepting Risk –subjective, based on person's or society's judgement

- Overall LOC probability distribution for an ISS mission shall have a mean value no greater than… (NASA CCT-REQ-1130, 4.0)
  - **1 in 270**

Risk Acceptance Perception

Ocampo, R., Klaus, D. (2013). A Review of Spacecraft Safety: From Vostok to the International Space Station. New Space 1(2): 73-80

Risk Metrics	Comparison of Transportation System Fatalities			
	Automotive	Railway	Commercial Aviation	Space Shuttle (~800 passengers)
Fatal Missions : Total Missions	N/A	N/A	1 : 334,247	1 : 68
Fatalities : Total Mission	N/A	N/A	1 : 192,835	1 : 10
Fatalities : Total Passengers	1 : 95	N/A	1: 14,800,000	1 : 58
Fatalities : Total Miles	1 : 87,719,298	1 : 34,333,333	1 : 19,746,153,846	1 : 38,802,507
Fatalities : Total Passenger-Miles	N/A	N/A	1 : 346,154	1 : 242,591,494

Soyuz 119 missions (Sept 2013): 2 fatal missions (1:60), 4 fatalities (1:30), 2 aborts

Utilization Metric Development

Human-Rating → **Protect, Accommodate, and Utilize the Crew**
But how do you measure <u>utilization</u> of crew?

Problem

Crew Utilization (i.e. performance) not well-characterized and thus hard to monitor, maintain, and resolve throughout mission.

Literature Review

Currently over 300 different Human Performance Methods and Tools to choose from with different areas of applicability.

While human performance has been examined, it is still not well-quantified, nor are there standard metrics for its use.

Blumberg and Pringle (1982)

Approach & Methodology

1) Characterize Crew Performance Metrics
2) Assess needs for different Mission Profiles
3) Quantify, evaluate and validate metrics

Duration \ Destination	Up to LEO	Beyond LEO
Short (< 2 weeks)	Suborbital LEO **A**	Lunar Orbit, Lunar Surface, Surface Ascent/Descent **B**
Long (> 2 weeks)	ISS **C**	Lunar Surface, Mars Orbit, Mars Surface, NEA **D**

Christine Fanchiang, PhD student

Results or Schedule/Milestones

COE CST Task 184 Report Documentation

- Human Spaceflight Terminology and Definitions. Updated: 1 Oct 2013.
- Human Spaceflight Safety Terms and Definitions. Updated: 1 Oct 2013
- Human Spaceflight Safety Perspectives. Updated: 1 Oct 2013

- Review and Comments to the FAA Established Practices for Human Spaceflight Occupant Safety DRAFT July 31, 2013

Results or Schedule/Milestones

COE CST Task 184-Related Publications & Presentations

- Ocampo, R., Klaus, D. (2013). A Review of Spacecraft Safety: From Vostok to the International Space Station. *New Space* **1(2)**: 73-80
- Fanchiang, C. and Klaus, D.M. (2013) Defining a Crew Utilization Figure of Merit to Characterize Human Performance Influence on Spacecraft Design (*poster*) AIAA 43rd International Conference on Environmental Systems (ICES), Vail, CO, July 2013
- Klaus, D.M., Fanchiang, C. and Ocampo, R.P. (2012) Perspectives on Spacecraft Human-Rating. AIAA-2012-3419
- Fanchiang, C., Johnson, M. (2012) Evaluation of Commercial Human Space Flight Laws and Regulations in the United States. 63rd International Astronautical Congress, Naples, Italy, Oct 2012
- Fanchiang, C. (2012) Characterization and Evaluation of Manned Spacecraft Operability Factors. 63rd International Astronautical Congress, Naples, Italy, Oct 2012
- Fanchiang, C. and Klaus, D.M. (2012) Defining an Operability Index for Human Spacecraft Design (*poster*) AIAA 42nd ICES, San Diego, CA, July 2012
- Ocampo, R.P. and Klaus, D.M. (2012) Defining a Safety Index for Human Spacecraft Design (*poster*) AIAA 42nd ICES, San Diego, CA, July 2012

Next Steps

Assessment of risk mitigation implementation practices and strategies

BEST PRACTICES – A technique, method, process, activity, incentive, or reward that is believed to be more effective at delivering a particular outcome than any other technique, method, process, etc. when applied to a particular condition or circumstance.

PROTOCOL – A detailed plan for a scientific or medical experiment, treatment or procedure.

GUIDELINE – A statement by which to determine a course of action. [It] aims to streamline particular processes according to a set routine or sound practice. Guidelines are not binding and are not enforced.

CERTIFICATION – Designation that participants [or item being certified] have demonstrated the requisite, work-related knowledge, skills, or competencies and met other requirements established by the certification program provider (e.g., academic degree, specified number of years of occupational or professional experience).

LICESNSURE – A mandatory credentialing process established by a government entity. It is illegal for an individual to practice the profession without a license.

REQUIREMENT-BASED – Technique used in system engineering design in which specific functions are required for the system and each function must be verified for compliance.

Final Report: Considerations and Guidelines for Human-Rating of Commercial Space Transportation Systems

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