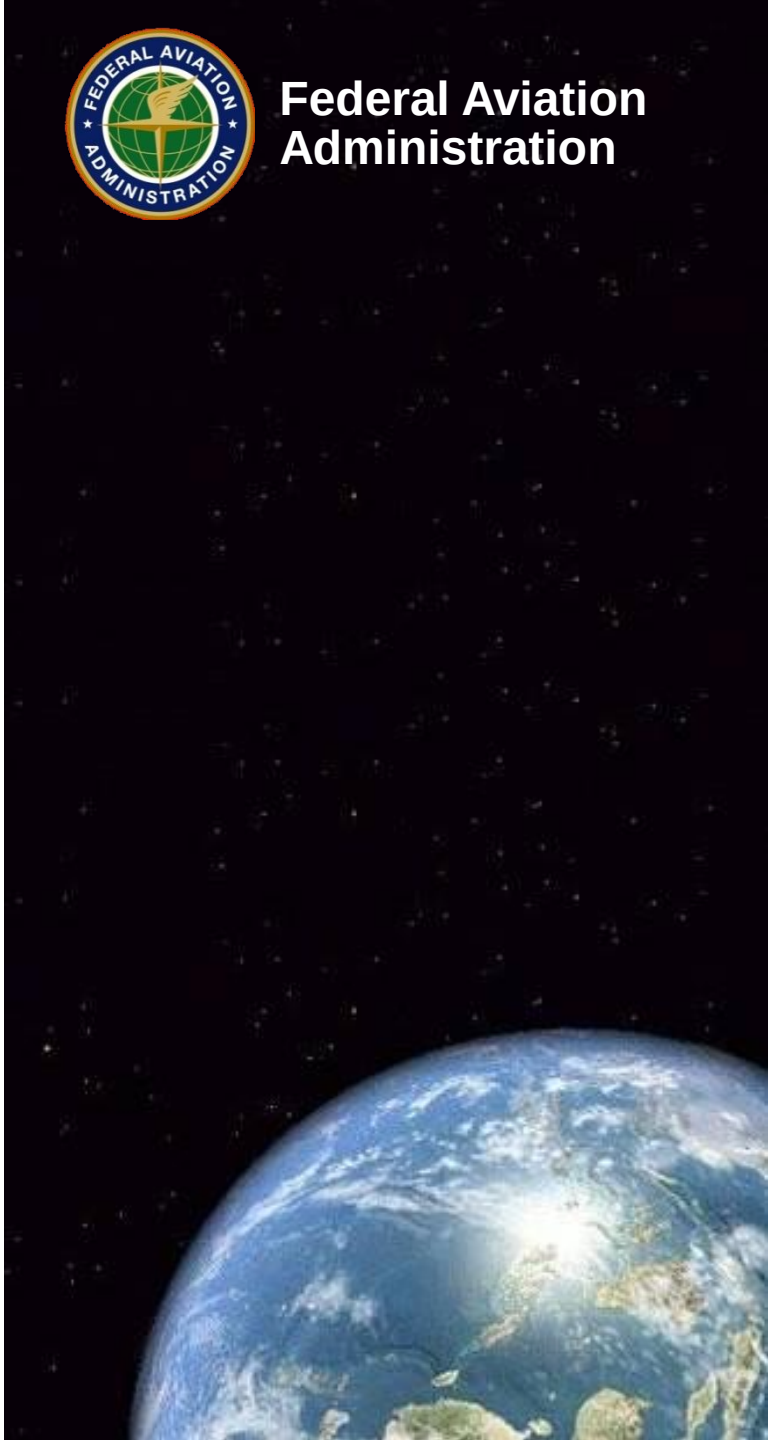
COE CST Second Annual Technical Meeting

Task 184
Human-Rating of Commercial Spacecraft

Prof. David Klaus
University of Colorado Boulder

Federal Aviation Administration



November 1, 2012

Overview

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

- *Related PhD Research*

Team Members & Affiliates

- **David Klaus**, PI, University of Colorado
- **Christine Fanchiang**, PhD student, CU Aerospace (funded by COE)
- **Pam Melroy, Jeff Sugar, Rene Rey**, FAA
- **Robert Ocampo**, PhD student, CU Aerospace (funded by SNC)
- **Mark Weyland**, NASA JSC
- **Kenneth Stroud**, **Merri Sanchez,** Sierra Nevada Corp.
- **Scott Norris, Todd Sullivan**, Lockheed Martin
- **Sheryl Kelley,** Boeing
- **Tim Bulk**, Special Aerospace Services
- **Jeffrey Forrest**, Metropolitan State College of Denver

- Plus Working Group members (being formed)

Purpose of Task

- Purpose
  - Assess criteria for Human-Rating of commercial spacecraft to assist the FAA with informed decision making regarding regulatory aspects affecting safety from a technical perspective
- Objectives - *year 2* (6/1/12 to 5/31/13)
  - Identify and define pertinent Human-Rating Terms and Definitions
  - Assess existing FAA aviation design, production and operation certification processes to identify best practices that anticipate and guide the structure of future commercial spaceflight regulatory needs
  - Contribute to FAA 'Human-Rating Ground Rules and Assumptions'
- Goals
  - Develop baseline 'Human-Rating (Certification?) Guidelines and Considerations' for Commercial Space Transportation addressing requirements, validation & verification, and regulatory practices

Research Methodology

- Fundamental tenets underlying Human Rating are to:
  - **accommodate** physiological needs of the crew
  - **protect** the crew and passengers from harm, including ground crew and uninvolved public
  - **utilize** the crew's capabilities to safely and effectively achieve the goals of the mission

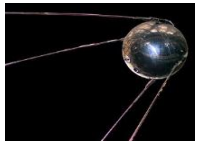
- Drives Life Support Requirements, Risk Mitigation Strategies, and Vehicle Functionality Design Goals, respectively

- Task focus is primarily on regulatory aspects related to safety

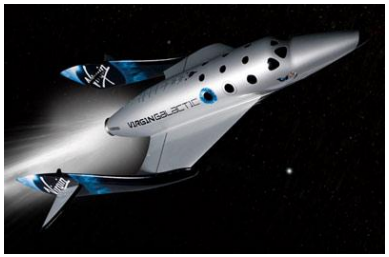
Human-Rating Considerations…

- **What does ‘human-rated’ mean?**
  - Usually LOC-based, how safe is ‘safe enough’?
  - What else besides ‘safety’ is considered?
- **How do we achieve / regulate it?**
  - Design functionality
  - Validation & Verification
  - Risk Analysis
  - Requirements-driven or Outcome-assessed?
  - Licensing? Certification?

Human-Rating Perspectives…

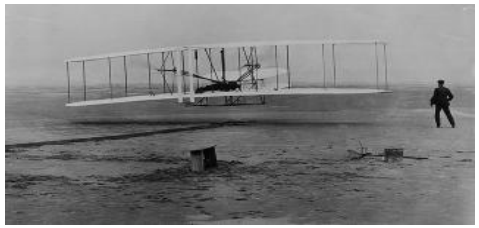




UNMANNED **ASTRONAUTICS** ***MANNED***

~100 years

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




Research Methodology

Σ S/C = *f* (physics) + *f* (physiology)

Non-negotiable Design Parameters

→ **required to effectively accomplish mission objectives**

Task 184 *PhD thesis*

+ *f* (safety) + *f* (operability)

Design Trade Space 'Figures of Merit'

→ **incorporated to reduce risk and improve crew utilization**

Research Methodology

1) Conduct literature review including NASA and FAA documentation
   - summarize current human-rating guidelines and prior outcome
   - evaluate existing FAA aviation design, production and operation certification processes

2) Examine related applications such as Building Certificate of Occupancy
   - bring analogous industry insight into the mix
   - help to anticipate the need for and guide the structure of future commercial spaceflight regulatory processes

3) Form Working Group of industry, government and academic partners who have vested interest in contributing to the effort
   - identify where consensus is attained and note where additional research is needed to resolve remaining philosophical and/or pragmatic differences on approaching human-rating
   - expect to address both legal and technical aspects.

Key Participants in 'Terms and Definitions' Working Group to date

- 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)

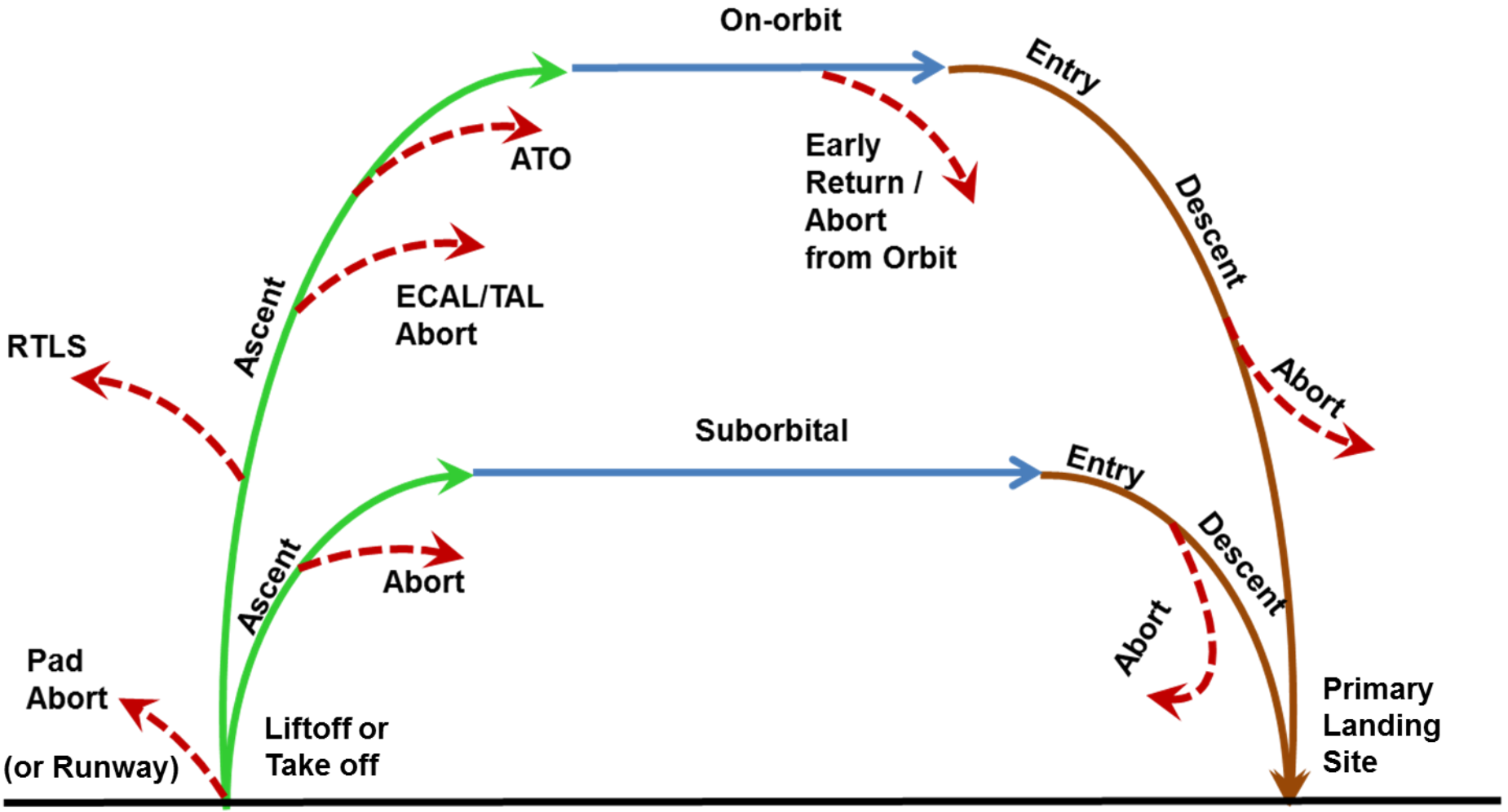
Results or Schedule/Milestones

- Task 184 was recently refocused to help support a related effort now underway by the FAA toward developing a Human-Rating Ground Rules and Assumptions (GR&A) document.

- Per our plans for the third calendar quarter of 2012
  - Completed a baseline version of a human-rating terminology and definitions with over 300 terms relevant to commercial human spaceflight with one or more definitions cited from 20 sources
  - Incorporated feedback from 18 interested participants across industry, academia and government (*in work*)

  - *Discussion of this effort being planned as a topic for an upcoming COMSTAC teleconference to gather feedback on process and key critical definitions, with emphasis on 'safe return to Earth'.*

‘Safe Return to Earth’ by Phase of Flight



Results

- Resultant publications and presentations this quarter include:

  - Klaus, D.M., Fanchiang, C. and Ocampo, R.P. (2012) Perspectives on Spacecraft Human-Rating, AIAA-2012-3419, 43rd AIAA ICES, San Diego, CA, July 2012 (paper and presentation)

  - Fanchiang, C., Defining an Operability Index for Human Spacecraft Design (student poster), 43rd AIAA ICES, San Diego, CA, July 2012

Next Steps

- 'Terms and Definitions' under review – upcoming COMSTAC topic

- Assess existing FAA aviation design, production and operation certification processes to facilitate open discussion aimed at identifying best practices to anticipate and guide the structure of future commercial spaceflight regulatory needs – **baseline target of December 31, 2012**

- Contribute to definition of FAA Human-Rating *Ground Rules and Assumptions* document intended to scope applicability of requirements as a function of mission phase, risk acceptance, etc., to be validated through thoughtful, systematic discussion with critical feedback from industry and public – **ongoing**

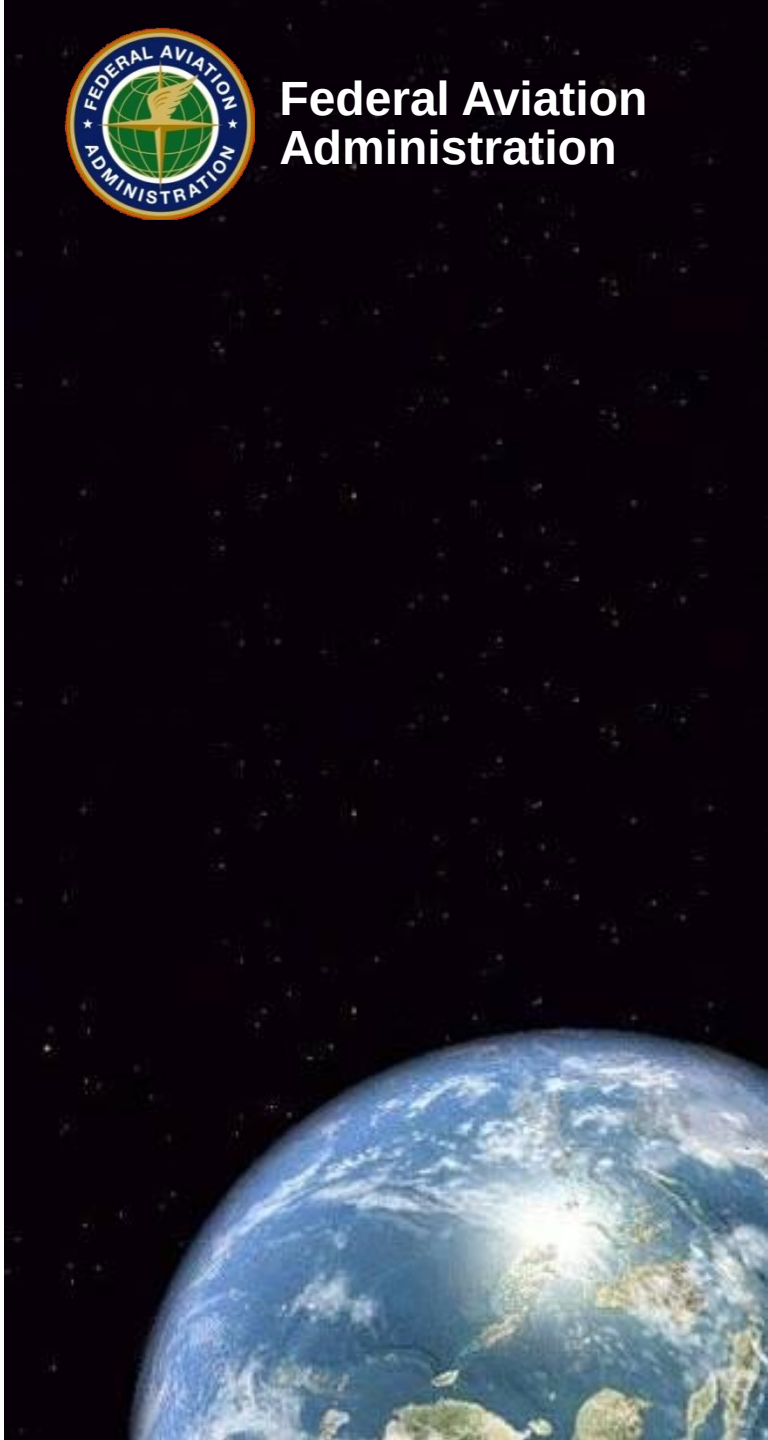
COE CST Second Annual Technical Meeting

Task 184
Human-Rating of Commercial Spacecraft

Christine Fanchiang
PhD Student
University of Colorado Boulder

November 1, 2012

Federal Aviation Administration



Human-Rating of Spacecraft

- Human spacecraft operate in an extreme and unique environment
- Internal spacecraft environment creates major challenges for space operations
  - Induced Spacecraft Environment
  - Demanding Spacecraft Operations
  - Degraded Human Performance

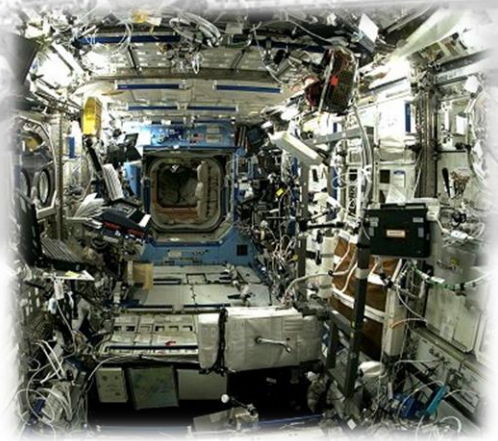


Image credit: nasa.gov

Research Motivation

- As human spaceflight increases in complexity and capability, need better understanding of design impacts on human performance
- Poor human performance increases risk to ***mission success*** and ***safety.***
- Currently, no clear indicator or criteria for determining how well spacecraft optimizes human performance
  - →What is considered optimal human performance?
  - →How does spacecraft design influence crew performance?

GOAL: Identify spacecraft design influences on crew performance and create an index for assessing spacecraft design

Factors Affecting Crew Performance

VEHICLE ENVIRONMENT	VEHICLE ARCHITECTURE	HABITABILITY
The natural and induced environment factors.	Factors that create the physical environment surrounding the crew.	Human needs of the system including aspects that affect crew's psychological well-being.
Internal Atmosphere	Décor	Food and Nutrition
Water	Anthropometric Accommodations	Personal Hygiene
Contamination	Habitable Volume	Waste Management
Acceleration	Location and Orientation Aids	Countermeasures
Acoustics	Translation Paths	Medical
Vibration	Hatches and Doors	Stowage and Inventory Management
Radiation	Windows	Sleep
	Lighting	Clothing
		Housekeeping
		Recreation
		Private/personal space

Human Performance Modeling

INPUTS:

Vehicle Accommodations:
Vehicle Environment

Vehicle Architecture

Habitability

Usability Factors:
Workspace Layout

Human/Machine Interface

Task-Specific Design

Integrated Factors (future):
-Work/task allocation
-Crew Interaction
...

HUMAN

Internal characteristics:
-Physiological adaptability
-Cognitive adaptability
-Psychological adaptability

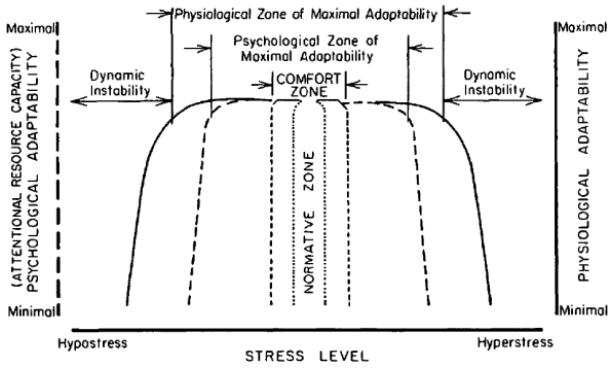


Image credit: *Hancock, 1989*.

OUTPUTS:

Physiological Metrics:
-HR
-Respiration
-Sensory Sensitivity Level
…

Cognitive Metrics:
-Processing Speed
-Workload Capability
…

Psychological Metrics:
-Irritability Level
-Emotional Stability
-Level of Happiness
…

Plan Forward

- Build descriptive model for human error
  - Model dynamics of human response
  - Identify more influential factors
- Test model components
- Verify model with historical spacecraft data

Contact Information

Professor David Klaus
Aerospace Engineering Sciences Dept.
University of Colorado / 429 UCB
Boulder, CO 80309-0429
303-492-3525
klaus@colorado.edu

Christine Fanchiang, PhD student
CU Aerospace Engineering Sciences
christine.fanchiang@colorado.edu