Human Rating Requirements for NASA's Constellation Program

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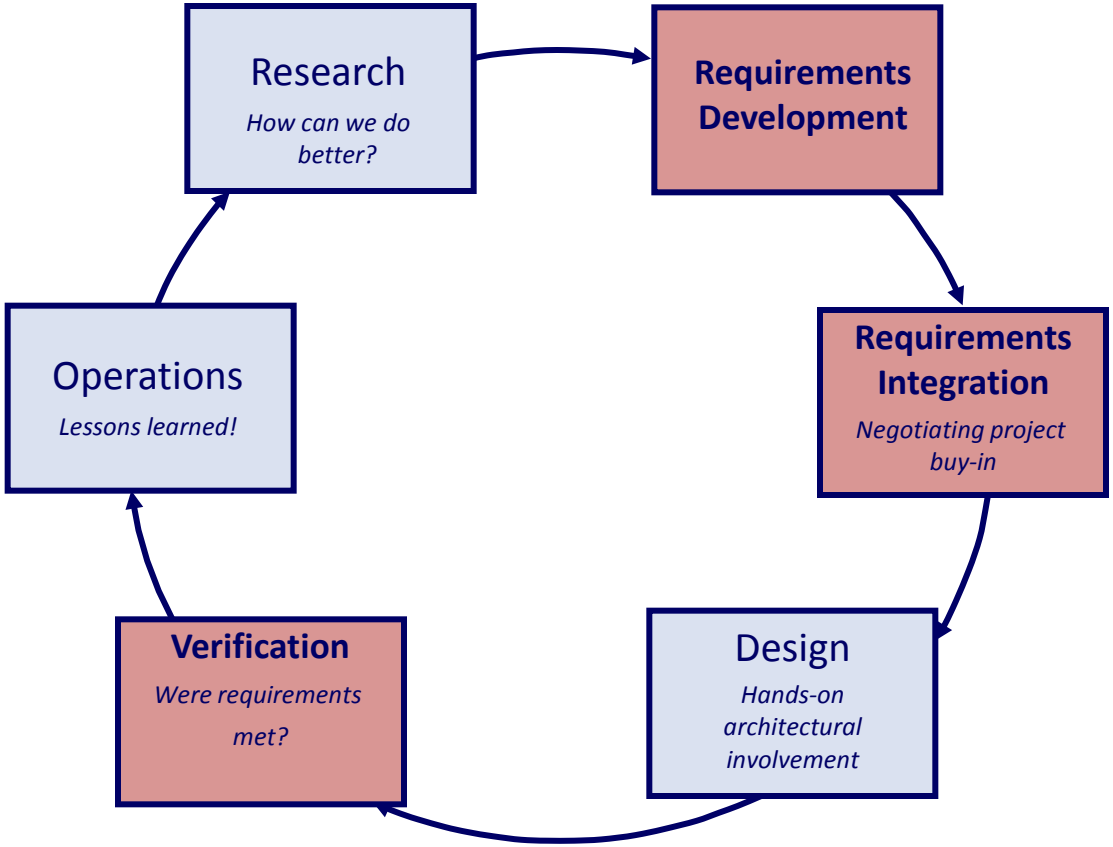
Panel : The Process to Keep the Human in Human Space Flight

Human System Integration Process



NASA Constellation Program (CxP) - Projects

CxP Project	Lead NASA Center	Developmental Phase	Operational Phase
Crew Exploration Vehicle – CEV (Orion)	JSC	Develop and test Orion spacecraft to transport crew to and from space	Provide Orion spacecraft
Ares	MSFC	Develop and test Ares I and Ares V launch vehicles	Provide Ares launch vehicles
Ground Operations	KSC	Perform ground processing and integrated testing of launch vehicles. Plan, construct and/or reconfigure integration, launch, and recovery services for Orion Crew Module, Ares I, and Ares V	Provide logistics and launch services. Provide post-landing and recovery services for the crew, Orion Crew Module, and spent Ares Solid Rocket Boosters.
Mission Operations	JSC	Configure, test, plan, and operate facilities, systems, and procedures. Plan missions and flight operations	Train crew, flight controllers, and support staff. Coordinate crew operations during missions.
Lunar Lander (Altair)	JSC	Develop and test the Lunar Lander to transport crew to and from the lunar surface and to provide a habitable volume for initial lunar missions	Provide Lunar Lander
Extravehicular Activities (EVA) Systems	JSC	Develop EVA systems (spacesuits, tools, and servicing and support equipment) to support crew survival during launch, atmosphere entries, landing, abort scenarios, and outside the space vehicle and on the lunar surface.	Provide spacesuits and tools
Lunar Surface Systems	JSC	Develop Lunar Surface Systems (equipment and systems for crew operation on the lunar surface) such as habitats, rovers, and construction systems	Provide Lunar Surface Systems

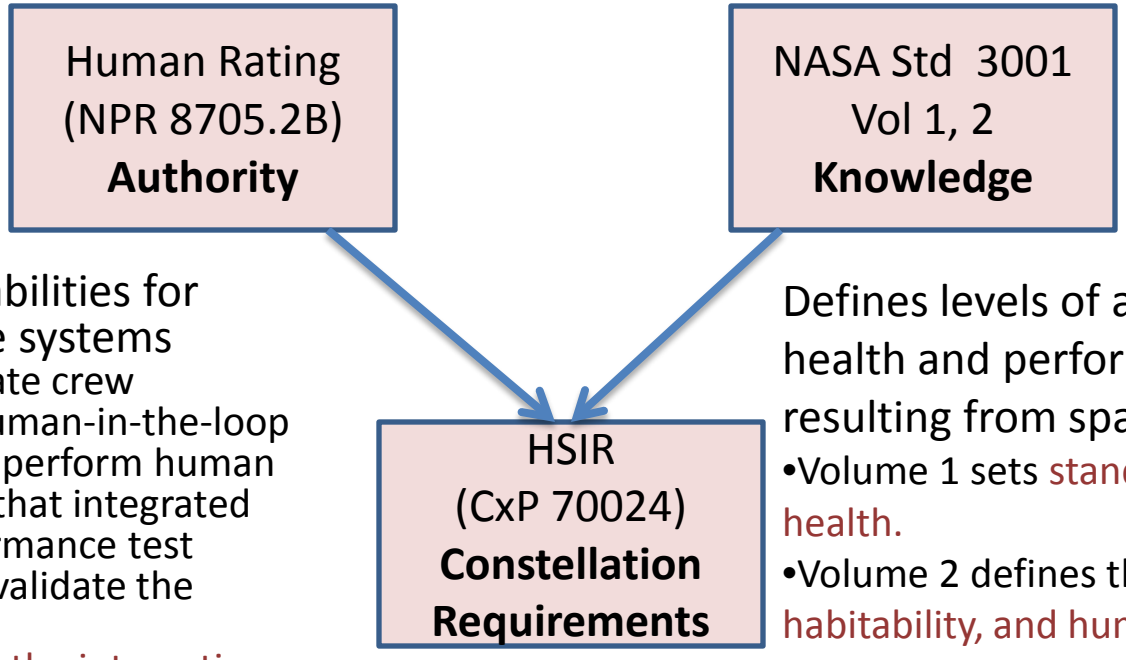
Table adapted from FORMULATION OF NASA's CONSTELLATION PROGRAM, Oct 2007

HSI in NASA's Constellation Program (CxP) via Human Rating Requirements - NPR 8705.2B

- The purpose of NASA Procedural Requirements (NPR) 8705.2B, Human Rating Requirements (HRR) document, is to define and implement the additional processes, procedures, and requirements necessary to produce human-rated space systems that protect the safety of crew members and passengers on NASA space missions.
- 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.
- Human-rating is an integral part of all program activities throughout the life cycle of the system, including design and development; test and verification; program management and control; flight readiness certification; mission operations; sustaining engineering; maintenance/upgrades; and disposal.

  The NPR is not levied directly on any of the Projects. Instead, CxP generates requirements which will meet the intent of the NPR and then flows those down to the Projects via allocation matrices.

Relationship of NASA Standards to HSIR



Benchmark of capabilities for human-rated space systems
- Directs CxP to evaluate crew workload, conduct human-in-the-loop usability evaluations, perform human error analysis, prove that integrated human-system performance test results were used to validate the system design
- Focuses primarily on the integration of the human into the system to prevent catastrophic events during the mission

Defines levels of acceptable crew health and performance risks resulting from spaceflight.
- Volume 1 sets standards related to crew health.
- Volume 2 defines the environmental, habitability, and human factors standards related to environmental health and human-system interfaces

- Human-Systems Integration Requirements – HSIR (**CxP** 70024 Rev C)
  - Defines parameters of a habitable environment, capabilities and limitations of the flight and ground crew that drive the design of the CxP Architecture systems to achieve mission objectives, and provides the parameters that protect the health and safety of the crew and allows them to perform their functions in an efficient and effective manner
    - Key mechanism to achieve human rating
    - Enables proper integration of human-to-system interfaces for all mission phases
    - Applicability matrix allows allocation down to each project as appropriate
  - Focuses on proper integration of human-to-system interfaces for all mission phases through applicable requirements.

Human Rating Requirements Flow Down Example - Handling Qualities

- Human-Rating Requirements for Space Systems (NPR 8705.2B) -HRR
  - HRR mandates the crew's ability to effectively control the spacecraft when necessary for mission completion or to prevent a catastrophic event.
    - It calls out an "accepted standard", Handling Qualities (HQ) for manual control of flight path and attitude
    - Names Cooper Harper Rating Scale as the means to measure handling quality
  - NPR requires that the Project determine and present proof of how the HQ requirements are integrated into system design, how to evaluate the design, leading to eventual verification and validation.
    - *(1) Human-rating is the process of designing, evaluating, and assuring that the total system can safely conduct the required human missions.*
    - *(2) Human-rating includes the incorporation of design features and capabilities that accommodate human interaction with the system to enhance overall safety and mission success.*
    - *(3) Human-rating includes the incorporation of design features and capabilities to enable safe recovery of the crew from hazardous situations*

[3.4.2] The crewed spacecraft shall exhibit Level 1 handling qualities (Handling Qualities Rating (HQR) 1, 2 and 3), as defined by the Cooper-Harper Rating Scale, during manual control of the spacecraft's flight path and attitude

Tracing Requirements - Human Rating to HSIR In the Example of Handling Qualities

- Human Systems Integration Requirements (HSIR) CxP 70024 Rev C
  - HSIR has two requirements for Handling Qualities – allocated to Orion (CEV) and Altair (Lunar Lander)
    - One requirement for Loss of crew or vehicle; One for Loss of mission
    - Verification specified as analysis and test
      - Task based and via Cooper Harper Rating Scale

[HS7003] The system shall have handling quality ratings of 1 or 2 on the Cooper-Harper Scale for tasks that can result in loss of crew or loss of vehicle.

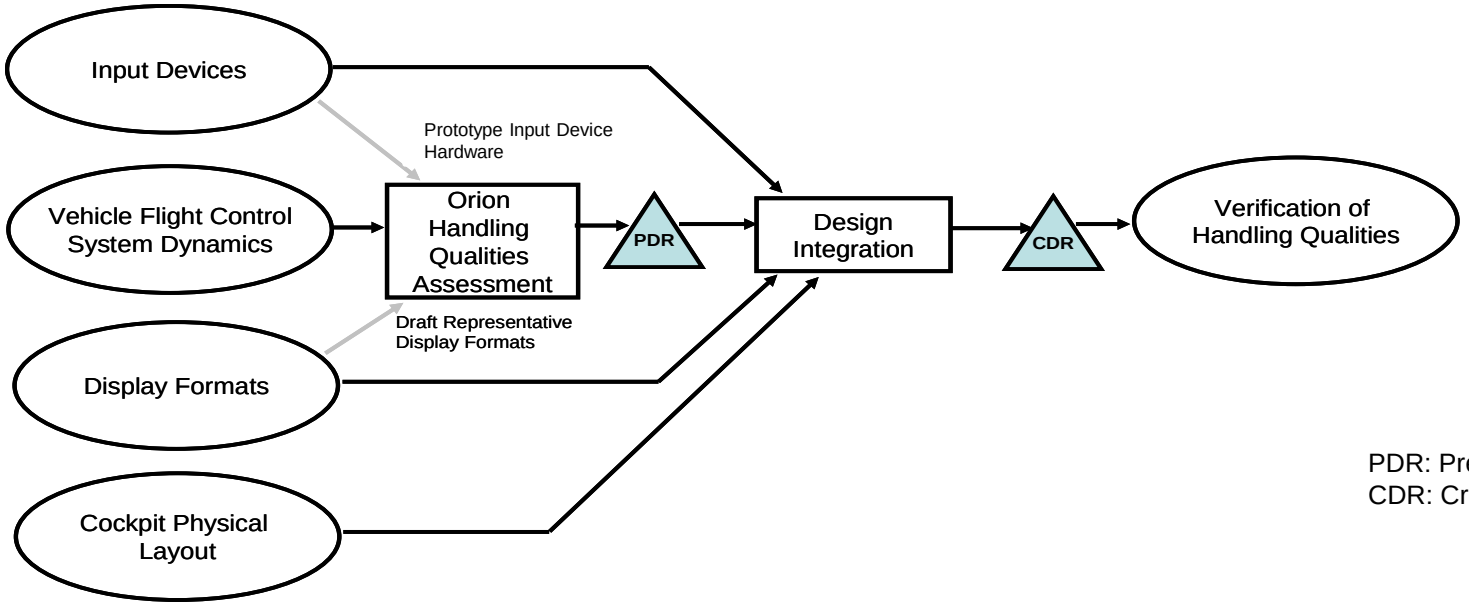
[HS7003V] The crew-safety handling quality rating shall be verified by analysis and test. The analysis (task analysis) shall identify the list of tasks in which errors can result in loss of crew or loss of vehicle. The test shall consist of at least 5 crew trained as operators performing the listed control tasks in a flight-like simulator or mockup and providing handling-quality ratings on the Cooper-Harper scale. The verification shall be considered successful when the analysis with test shows that, for all tasks that could result in crew or vehicle loss, no individual Cooper-Harper rating exceeds 2.

[HS7004] The system shall have handling quality ratings of 1, 2 or 3 on the Cooper Harper Scale for tasks that can result in loss of mission.

[HS7004V] The mission-safety handling quality rating shall be verified by analysis and test. The analysis (task analysis) shall identify the list of tasks in which errors can result in loss of mission. The test shall consist of at least 5 crew trained as operators performing the listed control tasks in a flight-like simulator or mockup and providing handling-quality ratings on the Cooper-Harper scale. The verification shall be considered successful when the analysis with test shows that, for all tasks that could result in mission loss, no individual Cooper-Harper rating exceeds 3.

Integration of Handling Qualities Requirements

- Orion (CEV)Project established a Handling Qualities Working Group (WG) to determine how the handling qualities requirements could be addressed early in the design and throughout the life cycle as the design matures.
- WG is an integrated team with participation by key stakeholders including vehicle designers, mission operations, crew office, human engineering, mockup developers, etc
  - Credible scenarios are generated to scope limits on when the handling qualities requirements apply
  - Decisions are made on when and how human in the loop tests will be conducted
  - Hardware and software availability and fidelity is determined
  - Simulation software fidelity for flight vehicle dynamics including Guidance, Navigation, and Control (GN&C) algorithms is established
  - Mockup state of readiness and availability is assessed



PDR: Preliminary Design Review
CDR: Critical Design Review

Figure courtesy G. Vos *Orion Spacecraft Handling Qualities System Baseline Review 12/11/08*

Integration of Handling Qualities Requirements

- The HSIR handling qualities requirements presume that manual piloting adds margin to prevent loss of crew of loss of mission
- The Orion Project's iterative design/test/analysis approach allows the stakeholders to be engaged in the integration of the HQ requirements into vehicle and mission design.
  - Enables task based assessment approach based on piloting scenarios and current vehicle design
  - Buys down risk of loss of crew or loss of mission due to inadequate handling qualities or control margins
    - The risk management is part of the design process and the steps to mitigate identified risks are focused on reducing either likelihood that the event will occur or the consequences if it does occur

From NPR 8705.2B Human Rating Requirements (HRR) document ….

- Above all, human-rating is more than a set of requirements, a process, or a certification – it involves a mindset, instilled by leadership, where each person feels personally responsible for their piece of the design and for the safety of the crew.