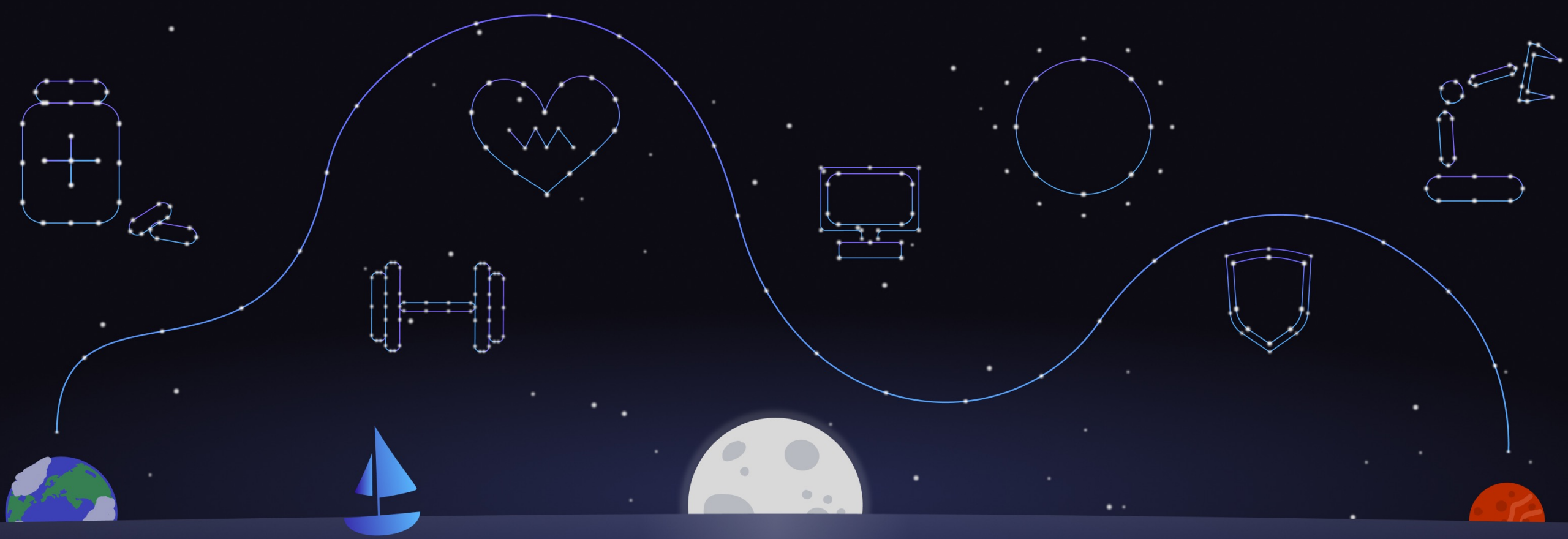
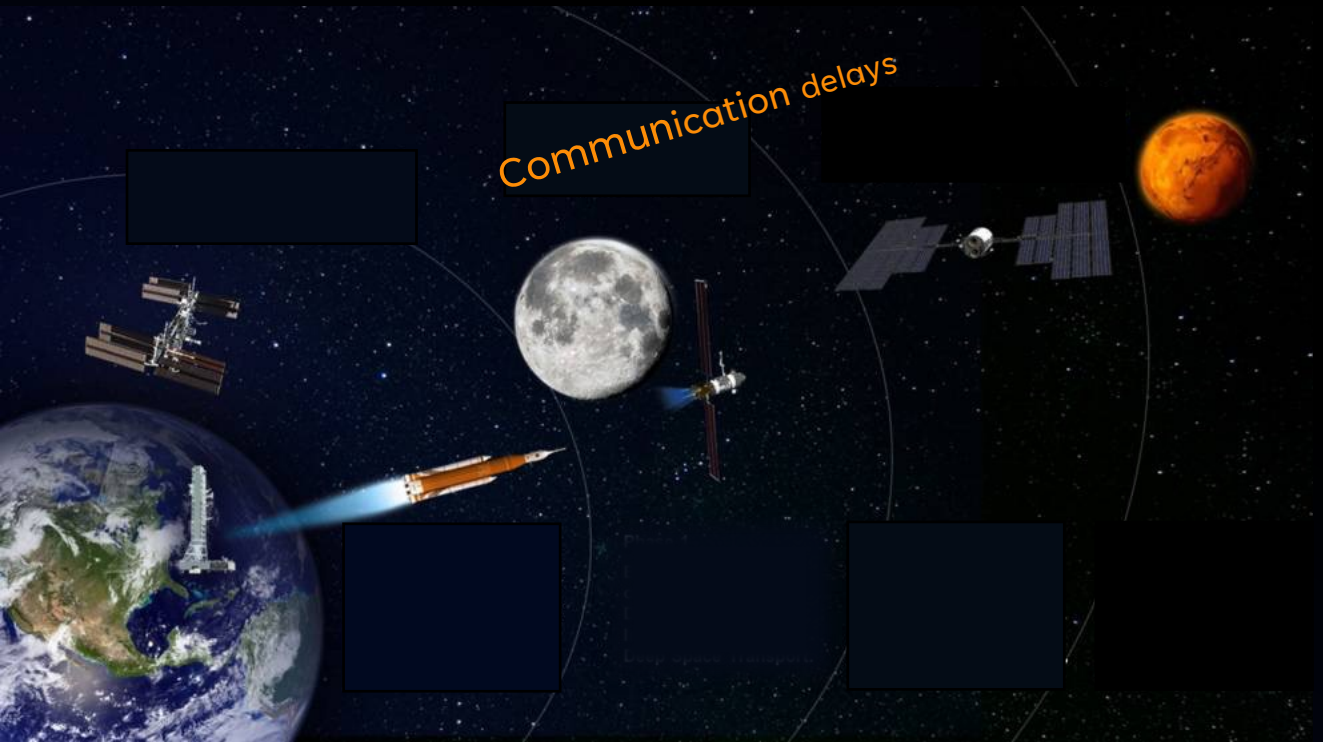


Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Bettina L. Beard, Ph.D.
NASA Ames Research Center
tina.beard@nasa.gov

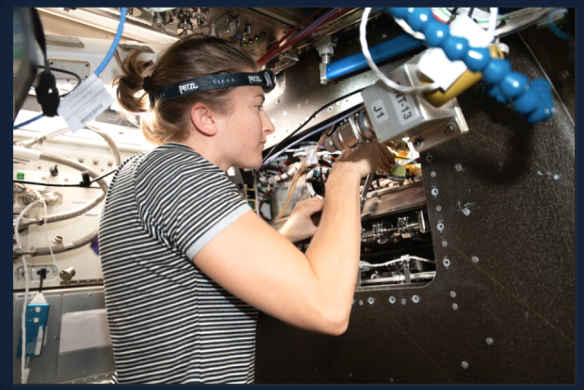
2022 NASA Human Research Program Investigators' Workshop



The Mission Evaluation Room (MER) 2006

Earth-Based Operations

Crew-Based Operations



Kayla Barron inspects cables inside
the Materials Science Research Rack

DRM Categories	Mission Type and Duration	Operations	
		LxC	Risk Disposition *
Low Earth Orbit	Short (<30 days)	5x2	Accepted
	Long (30 days-1 year)	5x2	Accepted
Lunar Orbital	Short (<30 days)	5x2	Requires Mitigation/Standard Refinement
	Long (30 days-1 year)	5x2	Requires Mitigation/Standard Refinement
Lunar Orbital + Surface	Short (<30 days)	5x3	Requires Mitigation
	Long (30 days-1 year)	5x3	Requires Mitigation
Mars	Preparatory (<1 year)	5x4	Requires Mitigation
	Mars Planetary (730-1224 days)	5x5	Requires Mitigation

Crew Performance Support System CPSS

Risk of Adverse Outcomes Due to Inadequate Human Systems Integration Architecture (HSIA)

Given increasing need for crew independence and greater operational complexity in future exploration missions, there is a possibility of adverse outcomes associated with deficiencies in Human Systems Integration, specifically that crew are

- unable to adequately respond to unanticipated critical malfunctions and/or
- perform safety critical procedures.

Critical, complex vehicle, habitat or human sub-systems will malfunction

Crew-Based Operations

Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS

Anomaly Response Processes

- Detect
- Troubleshoot / Diagnose
- Resolve / Treat
- Manage Contingencies

hazards from radiation, collision with space objects, atmospheric toxins, crew medical issue, surface landings, fire, etc.

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Anomaly Response Processes

- **Detect**
- Troubleshoot / Diagnose
- Resolve / Treat
- Manage Contingencies

hazards from radiation, collision with space objects, atmospheric toxins, crew medical issue, surface landings, fire, etc.

Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS

Anomaly Response Processes

- Detect
- **Troubleshoot / Diagnose**
- Resolve / Treat
- Manage Contingencies

hazards from radiation, collision with space objects, atmospheric toxins, crew medical issue, surface landings, fire, etc.

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Anomaly Response Processes

- Detect
- Troubleshoot / Diagnose
- **Resolve / Treat**
- Manage Contingencies

hazards from radiation, collision with space objects, atmospheric toxins, crew medical issue, surface landings, fire, etc.

Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS

Anomaly Response Processes

- Detect
- Troubleshoot / Diagnose
- Resolve / Treat
- **Manage Contingencies**

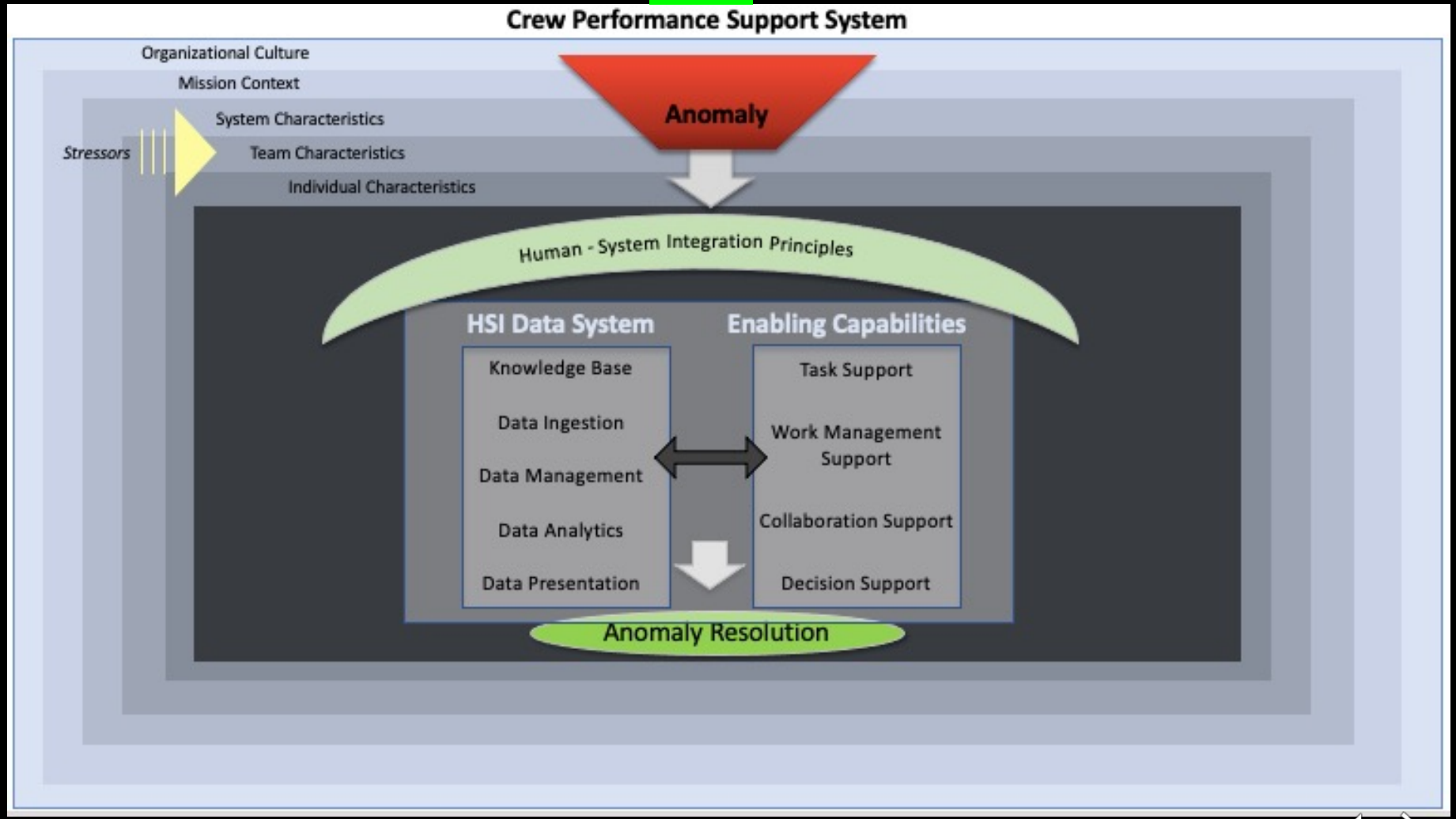
hazards from radiation, collision with space objects, atmospheric toxins, crew medical issue, surface landings, fire, etc.

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

CPSS

Context



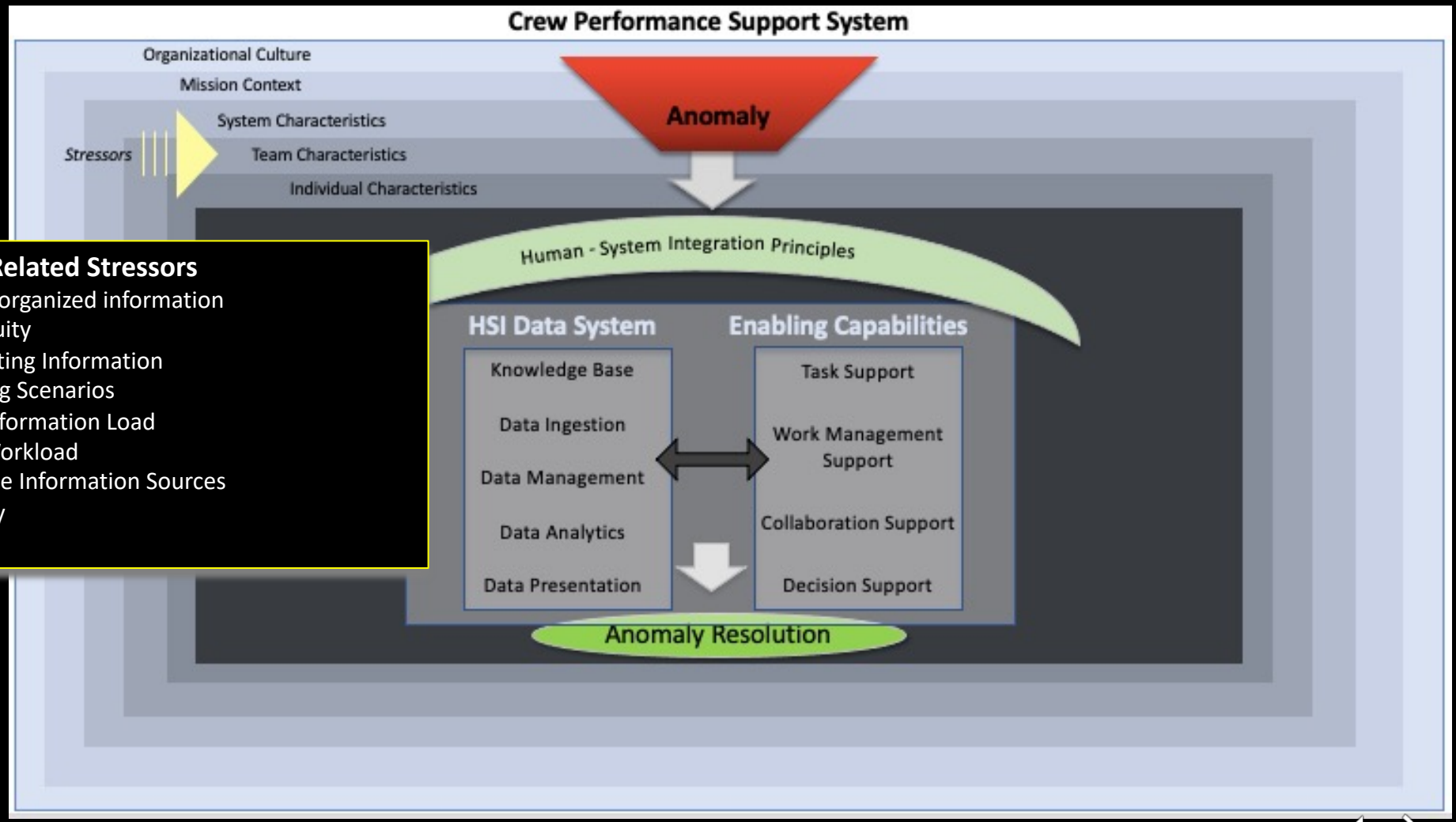
Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Stressors

Spaceflight Stressors
Atmospheric Toxins
Auditory Overload
Back Pain due to Time on Back
Catastrophic cost of making an error
Circadian Disruption
Communication Delays
Confinement
Cultural Differences between Crew
Decompression
Elevated Carbon Dioxide (CO2)
Fluid Shifts
Head Injury
High Workload
Isolation
Lunar Dust
Radiation
Sensorimotor disturbances due to gravity transitions
Side Effects from Medications
Threat
Vision Changes

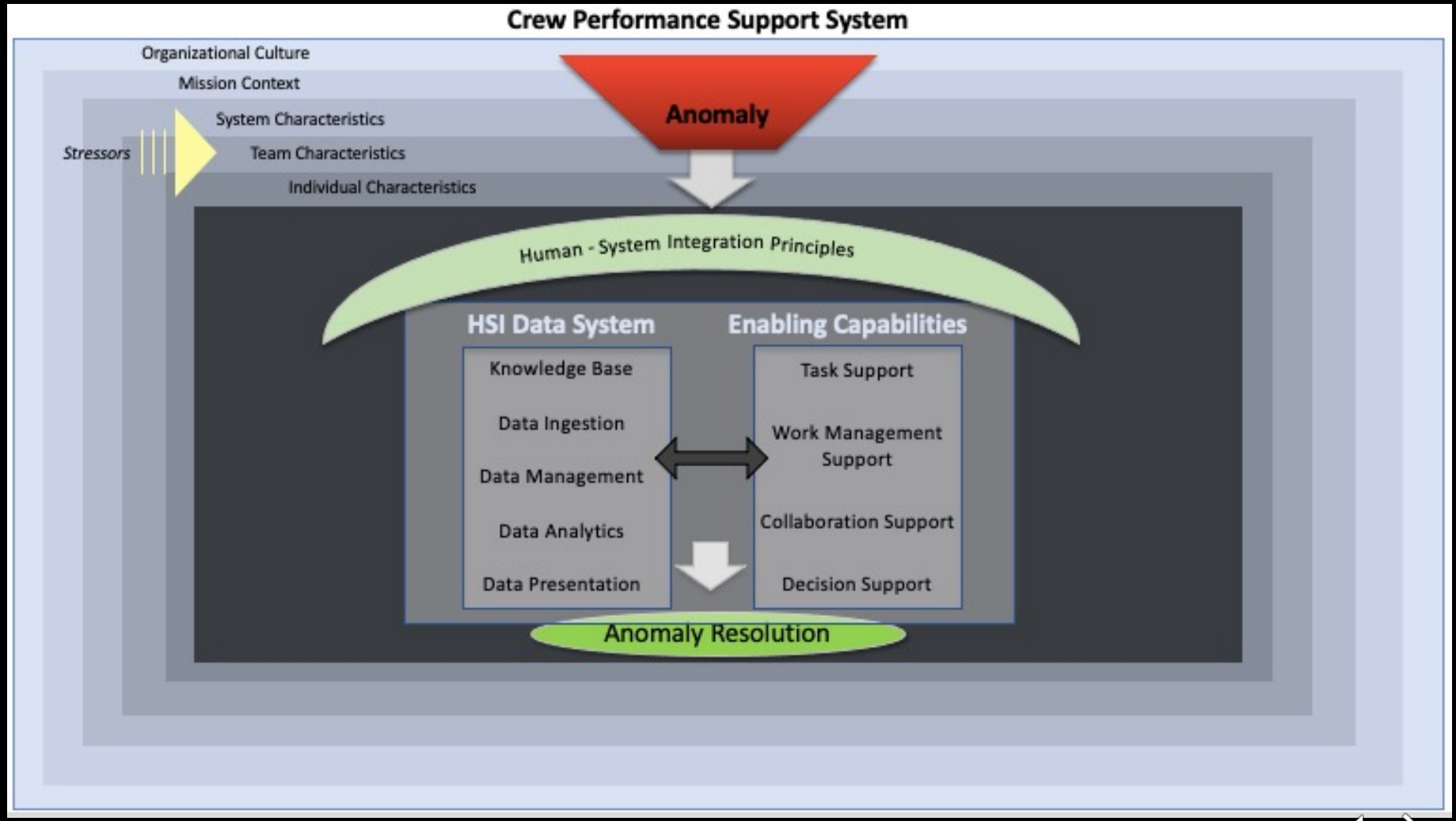
Task-Related Stressors
Poorly organized information
Ambiguity
Conflicting Information
Evolving Scenarios
High Information Load
High Workload
Multiple Information Sources
Novelty



Crew Performance Support System to aid in Anomaly Resolution

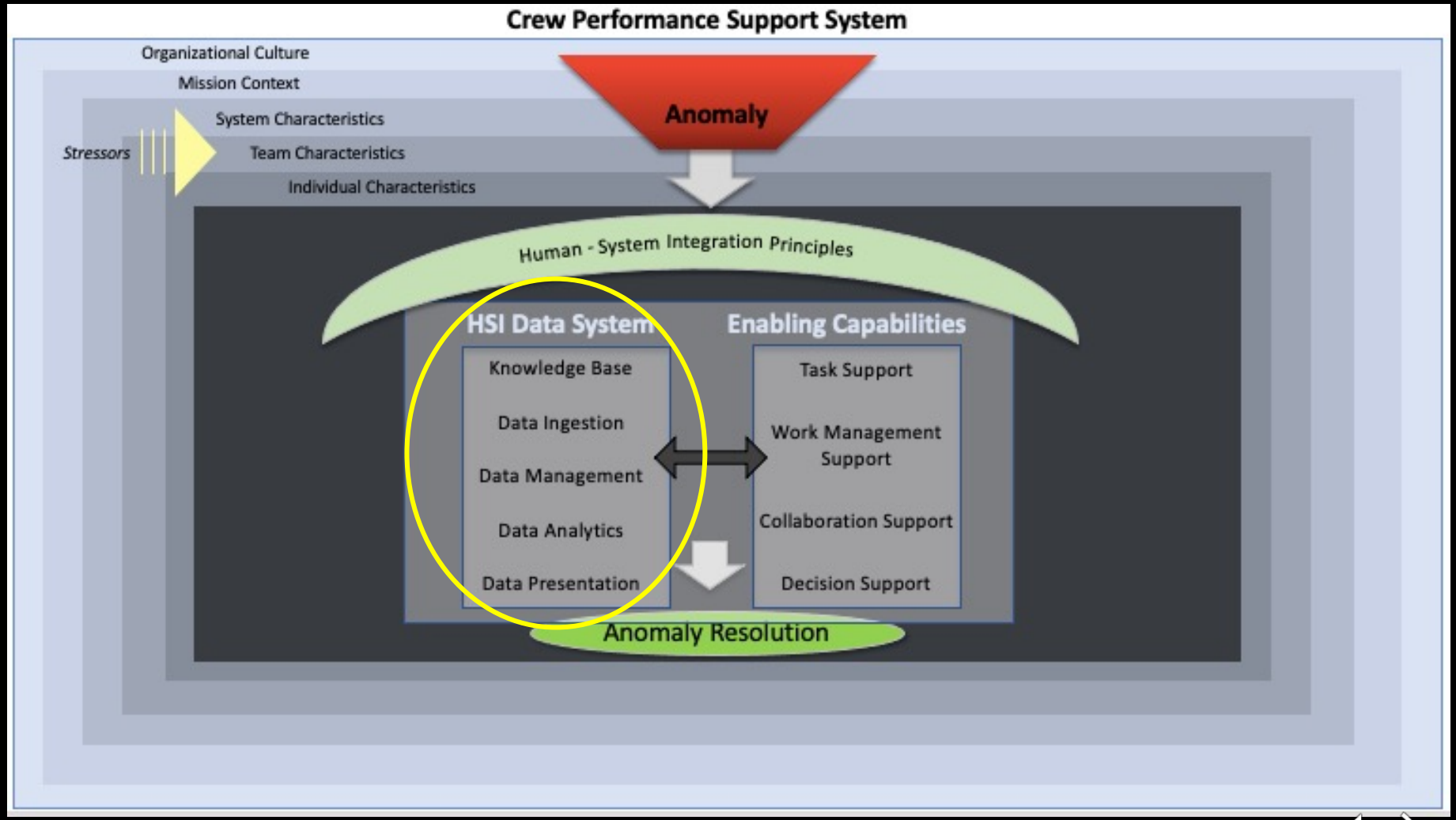
CONCEPT OF OPERATIONS

HSI



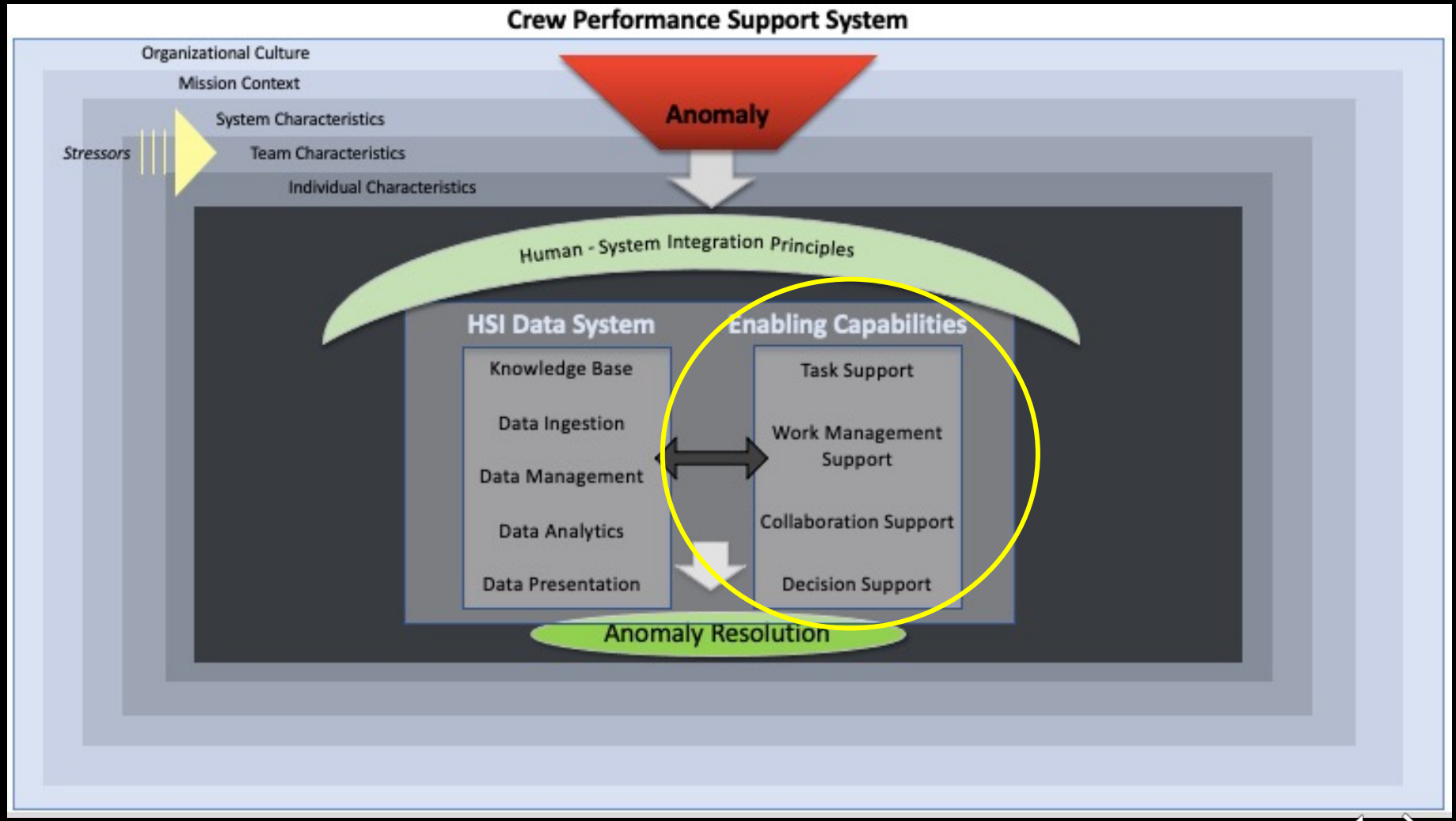
Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS



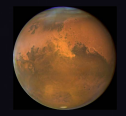
Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS



Exploration Enabling Capabilities

and exemplar processes, practices or technological goals



Knowledge Capture & Mgmt

Lessons Learned

Descriptive Analytics

Watch Item Trending

Knowledge-Based Decision Support

Troubleshooting & Analytics

Knowledge of Context

Integrated Visualizations

Data Integration

Crew Information Exchange

Crew/Ground Information Exchange

Collaboration Support

Intelligence Augmentation

Problem-Solving Prompts

Crew/Robot Information Exchange

Activity Scheduling

Triage Support

Integrated Schedule, Procedures, Inventory

Work Management Support

Multimodal

Smart Alarms

Data Storage Management

Smart Tutoring

Crew Can Create Agents as Needed

Task Support

CSCL

Smart Information Presentation

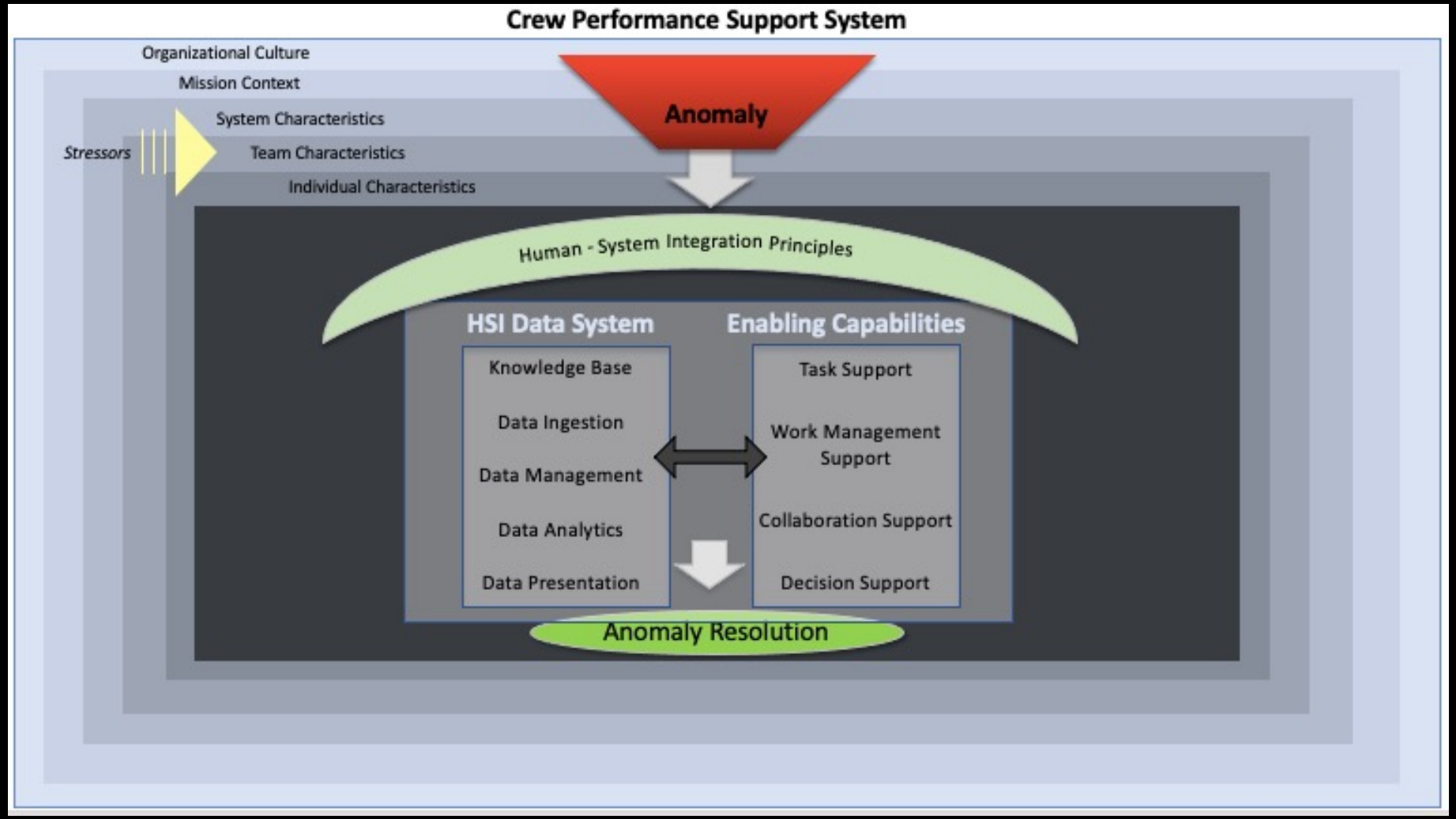
Machine Learning

Monitor Task Execution

Proactive Aiding

Crew Performance Support System to aid in **Anomaly Resolution**

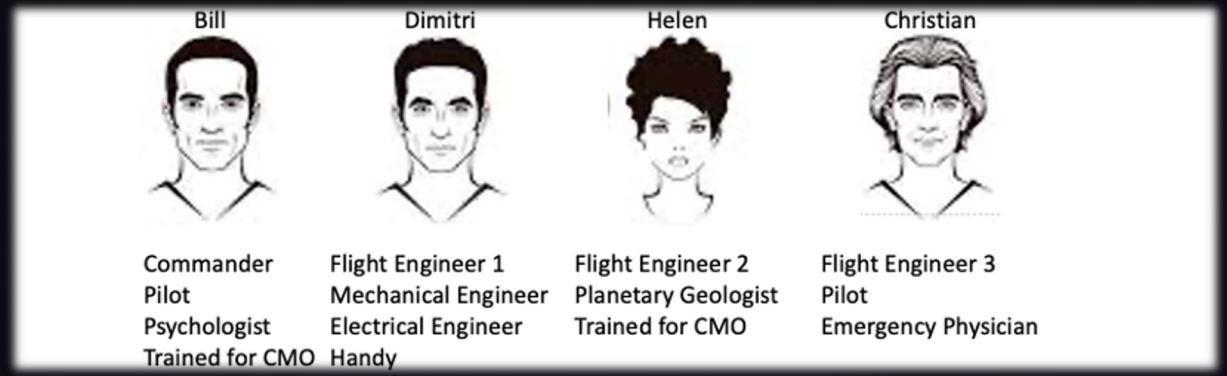
CONCEPT OF OPERATIONS



Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS

Meet the Crew



Crew Performance Support System to aid in **Anomaly Resolution**

CONCEPT OF OPERATIONS

Five Scenarios

En route ⟶ Comet Debris Field Event
EVA Preparation
Geological EVA
Robot Rescue
Radiation Event

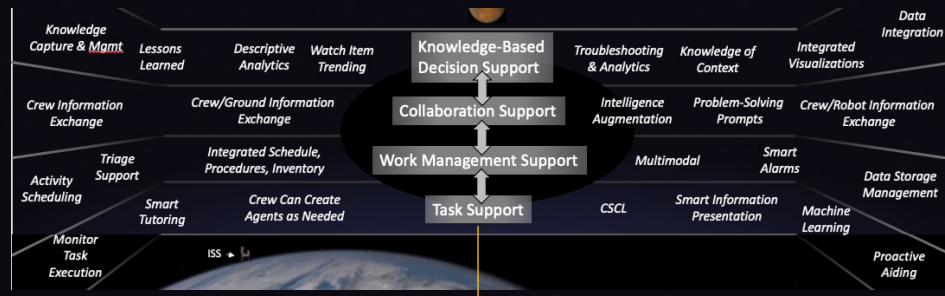
Table 8 - Comet Debris Field Event

Each row in the following table represents a point in time, with time flowing downward in the table. Anomaly A (first column) refers to the onset and resolution of a single anomaly. The column labelled Anomaly B refers to a second, concurrent anomaly. The third column identifies the CPSS capability (see Section 4.3.2.2) and a representative technological function. TS = Task Support; WMS = Work Management Support; CS = Collaboration Support; DS = Decision Support. The rightmost column provides the technical discipline(s) for which the CPSS has levied a requirement. These disciplines are recognized by the NASA Chief Technologist.[32] and were described in Section 4.3.2.3. Blue font is used for Anomaly A-relevant CPSS capabilities and exploration technologies.

The space capsule is *en route* to Mars and has flown through an undetected cometary debris field.

Anomaly A: Loss of Power	**Anomaly B: Loss of Cooling**[33]	**CPSS Capabilities and *Hypothetical Technology Function* (see Figure 7) Demonstrated (Blue text = Anomaly A)**	**Exploration Technology (defined by the NASA Chief Technologist and listed in Table 7) for which the CPSS levies requirements**
Smart sensors isolate the source of the issue, integrating a potential cascade of alarms into a single auditory alarm[34] accompanied by a message indicating that the habitat and service module are experiencing a significant power reduction.		WMS (*Smart Alarms*) WMS (*Multimodal Alerting*)	Power & Energy Storage Sensors & Instruments
The CPSS event recording capability is automatically triggered by the alarm onset e.g., records audio, keypresses, data, etc.		TS (*Event Driven Recording*) TS (*Proactive Aiding*)	
Power & Energy Storage and data analytics determine that life support power needs will not be met in ~5 hours at the current rate of loss. These data are pushed to the CPSS Data System. The CPSS presents these data and the trend graphically to the crew.		TS (*Proactive Aiding*) DS (*Models/Descriptive Analytics*) DS (*Integrated Visualization*)	Power & Energy Storage
FE-1 selects the Watch Item icon indicating that this trend must be monitored.		DS (*Watch Item*)	
The WMS capability lists 10 items using power that may be turned off without immediate consequence (e.g., won't compromise an experiment) to conserve power. FE-1, immediately turns OFF eight of these options, choosing to maintain full power to the CO_2 scrubbers for now. This change in state automatically triggers a recalculation of the power loss trend watch item.		TS (*Proactive Aiding*) WMS (*Monitor Task Execution*) DS (*Knowledge of Context*)	
Prior to the mission, previous spaceflight experiences, spaceflight data, lessons learned, procedures, etc. were acquired and stored.		DS (*Knowledge Capture & Management*) (*Lessons Learned*)	
FE-1 performs a digital search for historical records relating to a loss of power by stating "Critical loss of		TS (*Voice Recognition*) CS (*Crew-Automation Information Exchange*)	

Anomaly A: Loss of Power	Anomaly B: Loss of Cooling[33]	CPSS Capabilities and *Hypothetical Technology Function* (see Figure 7) Demonstrated (Blue text = Anomaly A)	Exploration Technology (defined by the NASA Chief Technologist and listed in Table 7) for which the CPSS levies requirements
entire crew.			
While viewing the communication pane, FE-1 sees that Earth-Support will receive notice of the ensuing power loss and trending data in approximately 15 min		CS (*Maintain* Earth-Support *Situation Awareness*) i.e., Provides information about when messages will be received on Earth	Communications
FE-1 selects access to the exterior camera feeds. He first accesses the port-side camera but does not see an obvious problem. He switches the image to the starboard-side and detects a large dark spot on one of the solar arrays adjacent to the junction box/power harness. The starboard solar array has been damaged by debris. He shares this information verbally. Earth-Support is automatically sent the images and the audio recording.	Suddenly, a warning alarm and message alerts the crew that a loss of pressure in external cooling loop B has been detected.	TS (*Smart Information Presentation*) Presents exterior camera views with rapid switching between cameras. WMS (*Smart Alarms*): e.g., Single alarm (rather than a cascade of alarms) that alerts the crew to a significant loss of cooling	Sensors & Instruments Communications
Although momentarily distracted by the second alert, FE-1 continues to read through the historical record and learns that the 2007 crew creatively used a cuff-link type device to pull and secure their solar panel rip.	The Commander states "Helen and Christian, please address that alarm"		
FE-1 recalls a similarly shaped device onboard, calls up the inventory tracking system and locates the item. FE-1 sends a text message that identifies the item to the Commander.	FE-3 requests a diagnostic on the external cooling system	DS (*Knowledge Capture*) WMS (*Inventory Tracking*) CS (*Crew Information Exchange*)	Thermal Management System
	FE-2 visually confirms and verbally states "Ammonia crystals near the external cooling loop".	CS (*Crew Information Exchange*)	
The Commander checks the loss of power trending graph watch item and sees that they now have 4.5 hours until life support power needs will not	FE-3, the physician, knows that FE-2 has been experiencing vision problems and provides a secondary confirmation of the ammonia crystals "Concur Helen,	DS (*Watch Item Trending*) CS (*Crew-Earth-Support Information Exchange*) CS (*Crew Information Exchange*)	Communications



DS = Decision Support
CS = Collaboration Support
WMS = Work Management Support
TS = Task Support

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Five Scenarios

Mars Surface →
- Comet Debris Field Event
- EVA Preparation
- Geological EVA
- Robot Rescue
- Radiation Event

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Five Scenarios

Mars Surface →
- Comet Debris Field Event
- EVA Preparation
- → Geological EVA
- → Robot Rescue
- Radiation Event

Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS

Five Scenarios

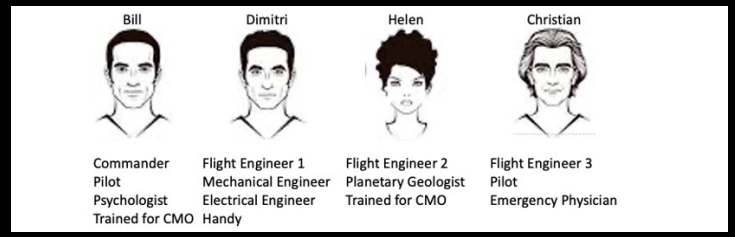
Comet Debris Field Event
EVA Preparation
Geological EVA
Robot Rescue
Return → Radiation Event

Payload Operations & Integration Center

Mission Evaluation Room (MER)

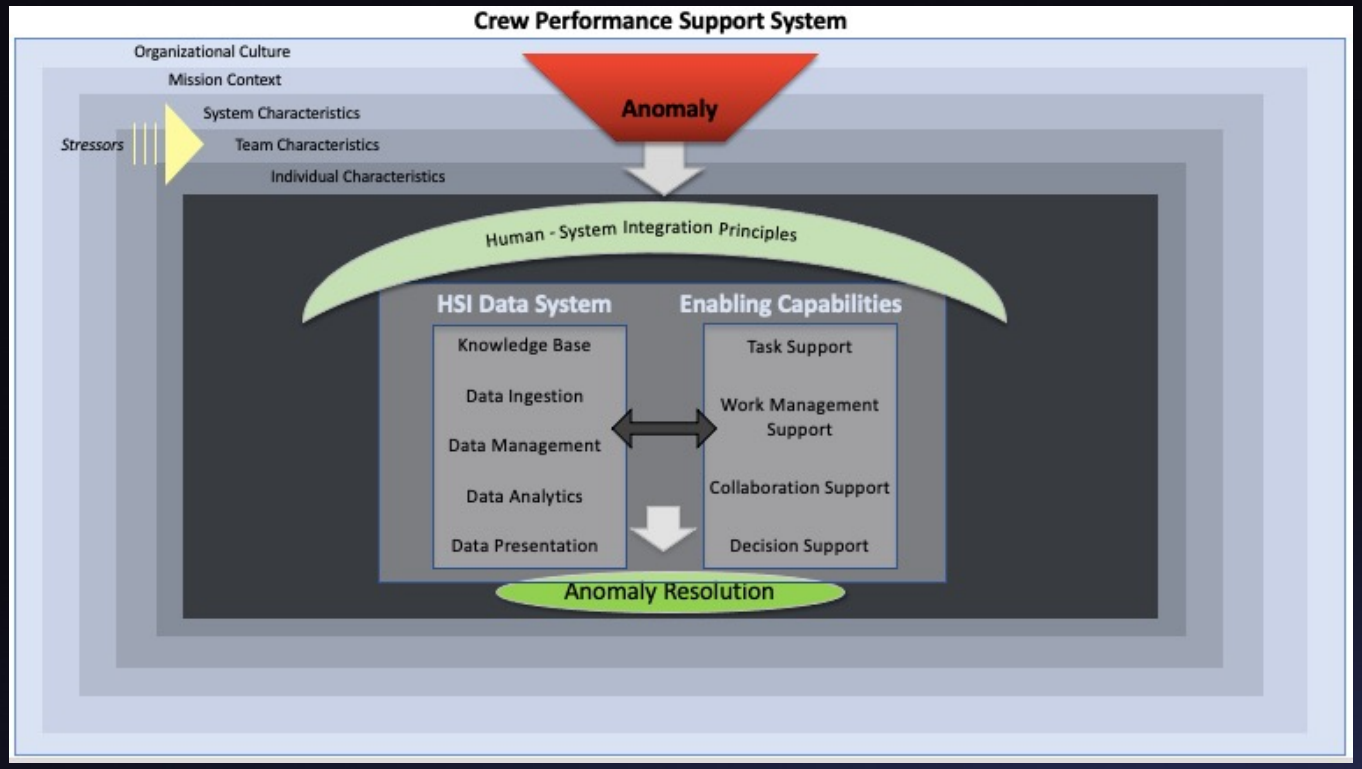
Mission Control Center (MCC)

50+ → 4-6



Crew Performance Support System to aid in Anomaly Resolution

CONCEPT OF OPERATIONS



HSIA ConOps Team

Lead: Tina Beard (ARC; Code TH)

Team Members: Donna Dempsey (JSC; Code SF)

Tina Panontin (ARC; SJSU)

Shu-chieh Wu (ARC; SJSU)

Brent Beutter (ARC; Code TH)

Alonso Vera (ARC; Code TH)

tina.beard@nasa.gov