What to Expect During In-flight Operations

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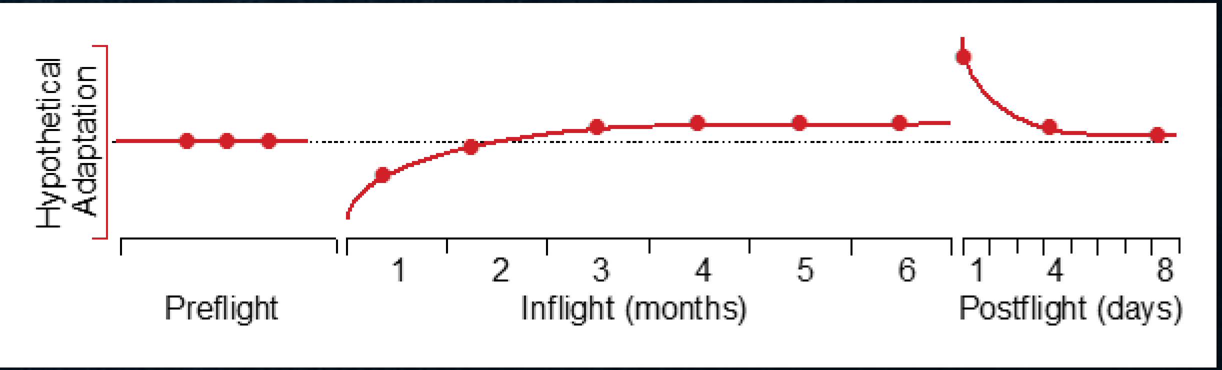
OVERVIEW

- Abstract: Executing human research on ISS has to navigate a unique risk environment. NASA planning efforts focus on an investigation's in-flight success but much of the threats to research objectives are not mitigated. A balanced requirement set affords the ability to remain flexible for each subject's data set while protecting the study's integrity across all subjects.
- Outline:
  - Shaping your expectations
  - Role of the PI for In-flight Operations
  - The ISS is in transition

SHAPING EXPECTATIONS -
PROTECTING YOUR DATA SET

- Our target is a complete data set across all subjects
- Due to the dynamic and often unpredictable ISS environment, it is highly probably that there may be a reduced data set or compromise due to competing priorities and nuances to the execution environment
- ISSMP relies on PIs to collaborate on when science loss transitions into subject loss.
- A best practice is to strategically develop a requirement set that is an appropriate balance of between requirements that can be implemented in a research environment that is not fully controlled.
- In-flight Goldilocks requirements
  - Too much flexibility cannot be defended
  - Not enough flexibility cannot be executed
  - Our target is a requirement set that is balanced and supported with scientific and/or statistical justification



- Complicating this Goldilocks approach – it is a moving target based on situation and how much data has been collected.

SHAPING YOUR EXPECTATIONS –
YOUR RESEARCH ENVIRONMENT

- Executing human research on the ISS requires investigators to navigate a unique risk environment.
- The competition for in-flight crew time, video, and data resources are carefully coordinated and planned months in advance to allow the ISS Program to provide the highest likelihood of success.
- In-flight crew time is the most restricted resource and this truth requires investigators to build flexibility into their scheduling requirements if they want the highest likelihood for success – a challenge for human research.
- Many investigations, especially those with human research elements, often have similar in-flight timing requirements and they cannot all be scheduled during the same week. Investigators should be prepared to justify the specific timing requirements and explain how flexible the timing of their in-flight operations are.

SHAPING YOUR EXPECTATIONS –

YOUR RESEARCH ENVIRONMENT

Biology & Biotechnology

Animal Biology
- Joint Rodent Research-1
- Rodent Research-5 (RR-5)
- Medaka Radiation
- Space Pup
- Mouse Epigenetics*

Cellular Biology
- CORM
- MYOGRAVITY
- NANOROS
- SERISM
- Cardiac Stem Cells
- Lung Cells
- Synthetic Bone
- Stem Cells

Macromolecular Crystal Growth
- CASISPCG6
- CASISPCG7
- CASISPCG8
- JAXA Low Temp PCG
- JAXA Medium Temp PCG
- JAXA PCG

Microbiology
- Microbial Tracking-2

Plant Biology
- BRIC-22
- BRIC-Light Emitting Diode (LED)
- Plant Habitat-01
- Payload Card-X (TangoLab-1)
- Petri Plants-2

Earth & Space Science

Astrobiology & Astrophysics
- CREAM (Ext)
- NICER (Ext)
- AMS-02 (Ext)
- Meteor
- CALET (Ext)
- MAXI (Ext)

Earth Remote Sensing
- CATS (Ext)
- CEO
- ISS RapidScat (Ext)
- SAGE III-ISS (Ext)
- STP-H5 FPS (Ext)
- STP-H5 LIS (Ext)
- DESIS
- NREP Inserts (Ext)

Near-Earth Space Environment
- SEDA-AP (Ext)

Education & Outreach

Cultural Activities
- Music and Space

Educational Competitions
- NanoRacks Module-9
- SPHERES-Zero-Robotics

Educational Demonstrations
- ISS Ham Radio
- Sally Ride EarthKAM
- AstroPi

Physical Science

Combustion Science
- ACME
- BASS-II
- Cool Flames Investigation
- ATOMIZATION

Complex Fluids
- ACE-T-8
- ACE-T-9
- ACE-T-6
- PK-4

Fluid Physics
- CFE-2
- DECLIC HTI-R
- Slosh Coating
- ZBOT
- Eli Lilly-Lyopholization
- NanoRacks-SMiLE
- Marangoni UVP
- Two-Phase Flow
- FLUIDICS

Fundamental Physics
- Cold Atom Lab (CAL)
- DOSIS-3D
- MAGVECTOR

Materials Science
- DECLIC DSI-R
- MSL SCA-GEDS-German
- Strata-1
- Nemak Alloys
- EML Batch 2
- MSL SCA-Batch 2b-ESA

Technology Development

Air, Water & Surface Monitoring
- Water Monitoring Suite

Avionics & Software
- ARAMIS
- Spaceborne Computer
- STP-H5 CSP (Ext)
- STP-H5 Space Cube - Mini (Ext)
- Telescience Resource Kit
- NanoRacks Module-63
- SG100 Cloud Computer

Characterizing Expt Hardware
- IN SITU
- ROSA (Ext)
- MVIS Controller-1
- ECHO

Communication & Navigation
- Maritime Awareness
- SCAN Testbed (Ext)
- Vessel ID System (Ext)

Food & Clothing Systems
- Skinsuit
- EVERYWEAR

Imaging Technology
- HDEV (Ext)

Life Support Systems
- Capillary Structures
- LDST
- MED-2
- UBNT

Microgravity Measurement
- STP-H5 SHM (Ext)

Radiation & Shielding
- PERSEO
- Miniaturized Particle Telescope
- Radiation Environment Monitor
- STP-H5 RHEME (Ext)
- PS-TEPC
- Radi-N2

Robotics
- Gecko Gripper
- Robonaut
- STP-H5 Raven (Ext)

Small Satellites Technologies
- NRCSD
- NanoRacks Small Satellite

Space Structures
- BEAM (Ext)
- RED-Data2

Spacecraft & Orbital Environmts
- RFID Logistics Awareness
- STP-H5 APS (Ext)
- STP-H5 GROUP-C (Ext)
- STP-H5 iMESA-R (Ext)
- STP-H5 LITES (Ext)

Spacecraft Materials
- STP-H5 ICE (Ext)

Thermal Management Systems
- Passive Thermal Flight Experiment
- Phase Change HX
- STP-H5 EHD (Ext)

Human Research

Bone & Muscle Physiology
- Intervertebral Disc Damage (P)
- Sprint
- Brain-DTI (P)
- EDOS-2
- MUSCLE BIOPSY (P)
- Marrow

Cardiovascular & Respiratory Systems
- Cardio Ox
- Cerebral Autoregulation
- IPVI
- Vascular Echo

Crew Healthcare Systems
- Medical Consumables Tracking
- Skin-B

Habitability and Human Factors
- Body Measures
- Fine Motor Skills
- Habitability

Human Behavior & Performance
- Lighting Effects
- Circadian Rhythms
- At Home in Space

Immune System
- Functional Immune
- Multi-Omics
- Probiotics
- Immuno-2

Integrated Physiology & Nutrition
- Biochem Profile
- Dose Tracker
- Repository
- Telomeres (P)
- Energy

Nervous & Vestibular Systems
- Field Test (P)
- NeuroMapping
- GRASP
- GRIP
- Space Headaches
- Straight Ahead in Microgravity (P)

Radiation Impacts on Humans
- ESA-Active-Dosimeters

HUMAN RESEARCH

Category TBD

NanoRacks Internal Modules	360 Camera
NanoRacks Module-55	Catalss
NanoRacks Module-56	Ceres
NanoRacks Module-67*	Crisstal
NR-Cavalier Space Processor*	ECHO
National Lab Airlock Cycle(s)	EPO Pesquet
ELF Investigation	ESA-EPO-TASK-LIST
ExHAM#1 (Ext)	HAPTICS-2/INTERACT
JAXA EPO TBD	Matiss
JAXA Payloads Place Holder	SARCOLAB-3
	SUPVIS-JUSTIN

Key

NASA	(P) = Pre/Post BDC only
National Lab	(Ext) = External

OTHER RESEARCH

Building flexibility into the requirements set is often the difference between having an in-flight session scheduled and losing the science.

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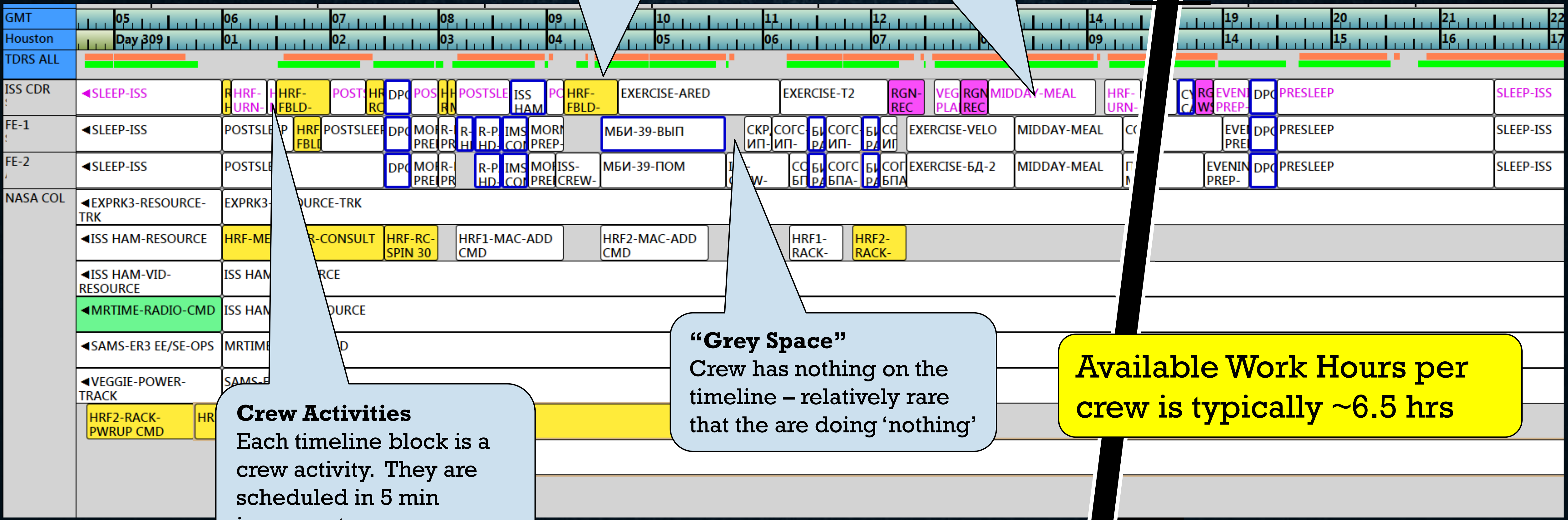
SHAPING YOUR EXPECTATIONS –
TYPICAL CREW DAY

Postsleep - Voice and Video are usually only available if offered by crew

Comm Bands
Voice and Video are *not* available at all times

Midday Meal
No more than 6 hours between meals



"Grey Space"
Crew has nothing on the timeline – relatively rare that the are doing 'nothing'

Crew Activities
Each timeline block is a crew activity. They are scheduled in 5 min increments

Available Work Hours per crew is typically ~6.5 hrs

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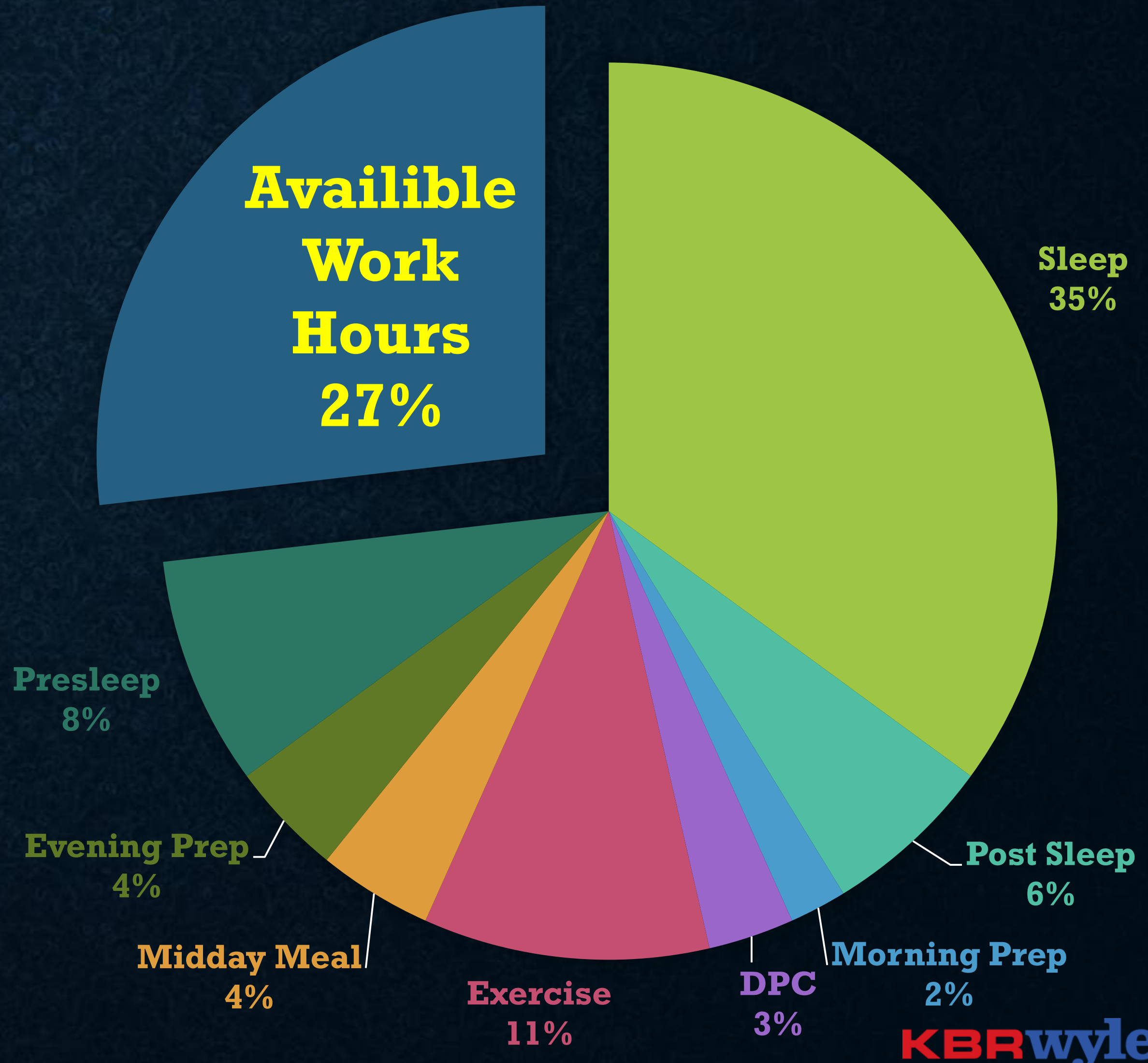
SHAPING YOUR EXPECTATIONS – CREWTIME

Activities scheduled within the "Available Work Hours" block include:

- Traffic Operations
- Medical Operations
- Onboard Training
- Routine Operations (including stowage management
- Public Affairs Office (PAO))
- Maintenance, Resupply/Outfitting
- EVA
- **Utilization Operations**



SHAPING YOUR EXPECTATIONS – EXECUTION LIMITATIONS

- Soyuz launch and rendezvous can take up to 48 hours before docking with the ISS.
- Crew has an adjustment period after arrival and utilization could be limited to strong science justification
- Utilization crewtime limited by vehicle dockings/undockings and EVAs
- Weekends are protected as off-duty days so weekend tasks for research are minimized
- Research constraints that make the implementation of their research sessions more difficult including:
  - Complicated in-flight sessions before the second week in-flight
  - More than five complicated in-flight sessions
  - A single session with one crewmember requiring 4 or more hours in 1 day.
  - Crew activity that must be performed daily or more than once a week.
  - Very precise/inflexible timing requirements for sessions
  - Extended, continuous activities over multiple days that could interfere with other operations.

THE PI IS ESSENTIAL TO IN-FLIGHT OPERATIONS

- Real-time
  - Support in MCC is not required but PI availability is needed when experiment activities are being performed
  - When issues arise, expect to not have all the details available and that decisions for protecting the data set will be difficult
  - WHAT-IFs all the time…
- Quantifying Science Loss
  - Be ready ahead of time and know when science loss will transition into subject loss
  - Your ISMSP interfaces don’t tell you that but we can help drive to that resolution
  - Situational
  - ISS has a long memory
- Data validation
  - Quick responses = quick recovery plan = most likely opportunity for avoiding science/subjet loss
- Protecting data integrity (Data Set)

ISS IS IN TRANSITION

- Utilization is now a priority and the ISS Program has been successful in removing execution barriers
- With the addition of a 4th USOS crew member by means of Commercial Crew vehicles, POIF is working on tools, processes, new cadre complement, and other enhancements to support:
    - An average of 68.5 crew hours per week
    - A maximum of 100 crew hours per week
- Opportunities are increasing
    - Utilization is being afforded more options
    - Human research is typically provided 'use-or-lose' situational priority due to the desire to avoid subject loss

SUMMARY

- The ISS is a truly unique research platform.
- The NASA International Space Station Medical Projects (ISSMP) maintains an expert team of professionals with the knowledge and experience to guide investigators through flight operations allowing investigators to address the human risks of spaceflight enabling the safe exploration of space.
- Building flexibility into the requirements can often mean the difference between having an in-flight session scheduled and losing the science
- A balanced requirement set affords the ability to remain flexible for each subject’s data set while protecting the study’s integrity across all subjects and research objectives.

BACKUP

- Executing human research on the ISS requires investigators to navigate a unique risk environment. A balanced requirement set affords the ability to remain flexible for each subject's data set while protecting the study's integrity across all subjects and research objectives.
- The competition for in-flight crew time, video, and data resources are carefully coordinated and planned months in advance to allow the ISS Program to provide the highest likelihood of success. In-flight crew time is the most restricted resource and this limitation requires investigators to build flexibility into their scheduling requirements. Many investigations often have similar in-flight timing requirements and they cannot all be scheduled during the same week. Investigators should clearly state the reasoning for specific timing requirements and explain how flexible the timing of their in-flight operations are. Building flexibility into the requirements set can often mean the difference between having an in-flight session scheduled and losing the science.
- All ISS crewmembers are currently launched on the Russian Soyuz spacecraft. The Soyuz is very space constrained and it is not feasible to perform any in-flight operations before docking with the ISS. After docking with ISS, crewmembers are typically busy with handover activities, and crew time for scientific activities is extremely limited for the first 2 weeks. Crew time is also limited during periods when other vehicles dock or undock due to required preparation activities, as well as around Extra Vehicular Activities. Weekends are protected as time off for crewmembers, and science is only performed if it is a crew preference And as a scheduling standard, crew workdays are 6.5 hours long and can also be limited due to the need for morning and evening coordination routines, lunch, and exercise.
- ISS crewmembers participate in multiple research studies during their mission including in-flight operations outside of human research. Investigators should be aware of potential on-orbit constraints that may impact implementation of their research sessions more difficult including:
- Complicated in-flight sessions before the second week in-flight (e.g., requires set-up of multiple pieces of equipment, followed by testing session of more than an hour or in-flight sessions that require privatized voice or video).
- More than five complicated in-flight sessions (e.g. requires set-up of multiple pieces of equipment, followed by testing of more than 2-3 hours that requires extensive privatized resources).
- A single session with one crewmember requiring 4 or more hours in 1 day.
- Crew activity that must be performed daily or more than once a week.
- Very precise/inflexible timing requirements for sessions (e.g., +/- window for testing of less than 1 week, multiple timed blood draws, sessions that are linked to other crew activities like meals, EVA's, crew wake/sleep, etc.)
- Extended, continuous activities over multiple days that could interfere with other operations.
- Depending on the concept of operations, an Investigator's responsibilities during in-flight operations are not limited to defining execution windows. Nominal planning, risk mitigation, execution scenarios, and the need for an impact analysis of science loss are a common occurrence. If data collection occurs as part of the investigation and that data is available to the Investigator team, a prompt validation of data provides the investigation with the most likely scenario for maintaining a nominal data set.
- The ISS is a truly unique research platform. The NASA International Space Station Medical Projects (ISSMP) maintains an expert team of professionals with the knowledge and experience to guide investigators through flight operations allowing investigators to address the human risks of spaceflight enabling the safe exploration of space.

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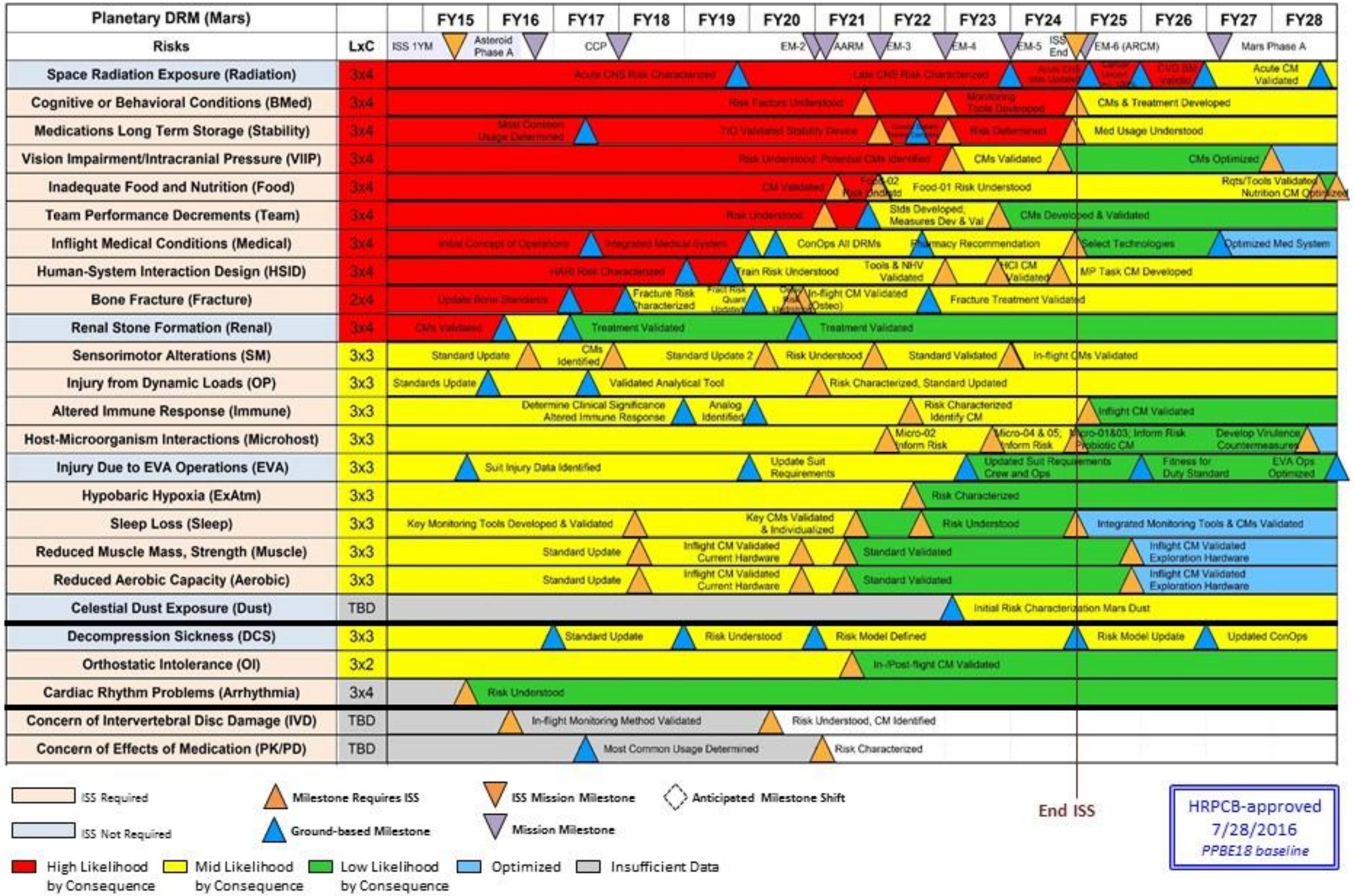
Human travelers to Mars will experience unprecedented physiological, environmental, and psychosocial challenges that could lead to significant health & performance decrements in the absence of effective mitigation strategies.

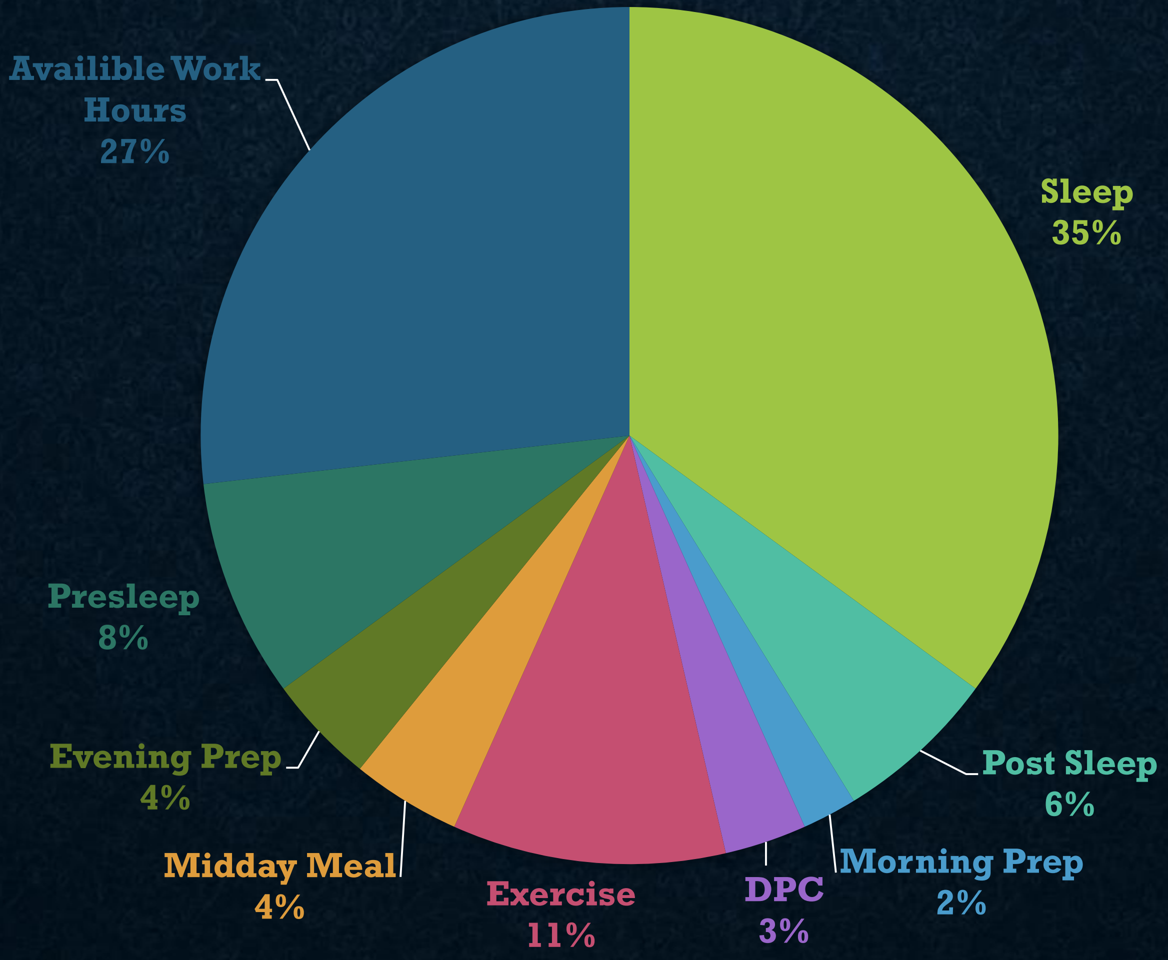
Success of any human mission to Mars will hinge on the mission designers' ability to develop and implement such strategies.

NASA's Human Research Program is responsible for identifying those strategies.

HRP Integrated Path to Risk Reduction, Rev D



CREW TIME


Availible Work Hours 27%
Sleep 35%
Presleep 8%
Evening Prep 4%
Post Sleep 6%
Midday Meal 4%
Exercise 11%
DPC 3%
Morning Prep 2%