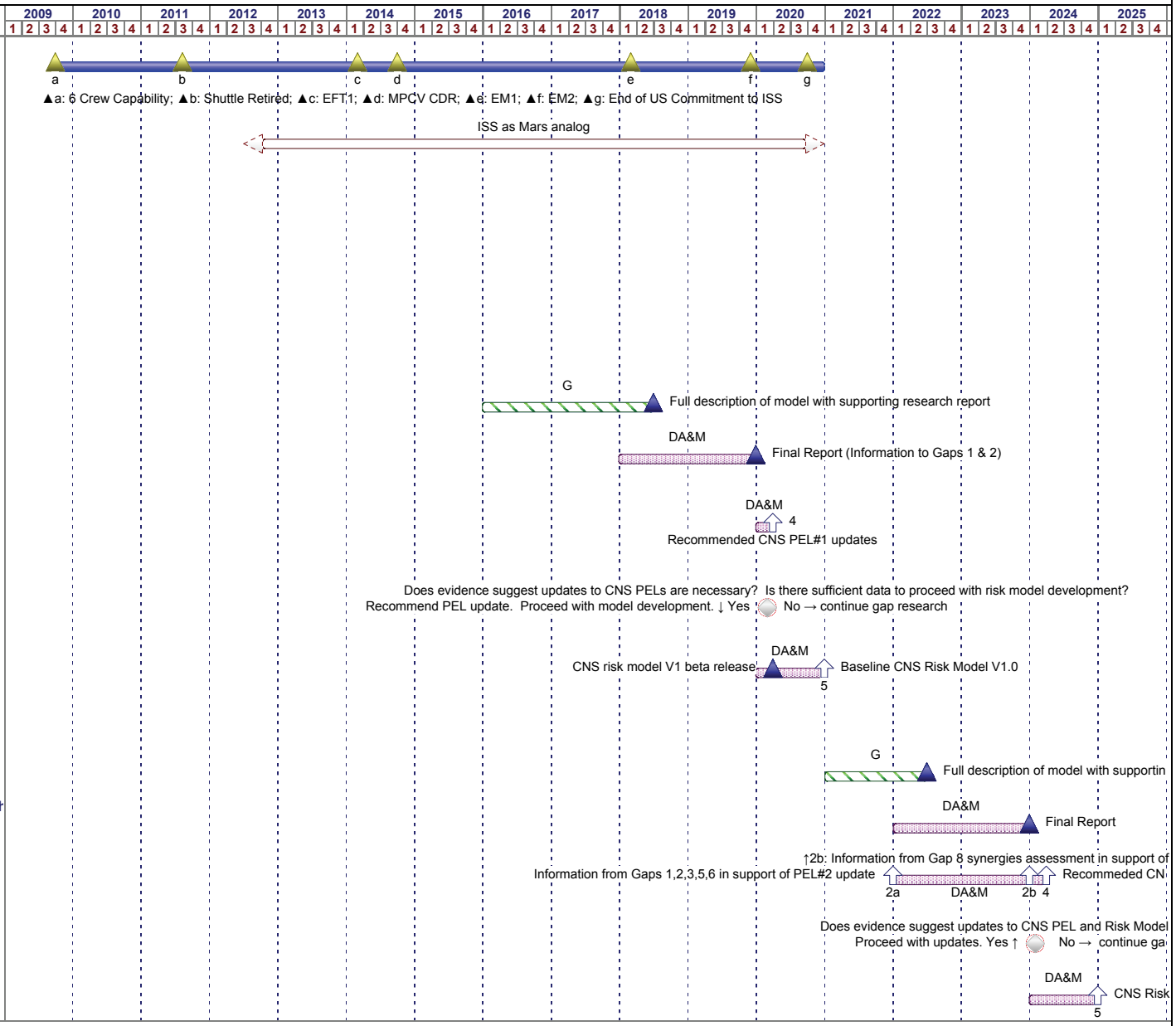
Summary		**Early Start**		**7) Countermeasure**	
G: Ground Study		**Task To Be Determined After Decision Point**		**8) Information To/From other Elements**	
F: Flight Study		**Major Milestone/Event/Accomplishment**		**9) Information to HSRB**	
L: Lunar		**1) Risk Characterization**		**10) Requirements**	
NSBRI		**2) Task↓↑Task**		**11) Study**	
DA&M: Data Analysis & Modeling		**3) Standards - New**		**Stop**	
FP: Flight Prep		**4) Standards - Update**		**Major Decision Point**	
AO: Add on to another study		**5) Tool**			
Planned/unfunded		**6) Technology**			


Task Name
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ISS and other vehicles
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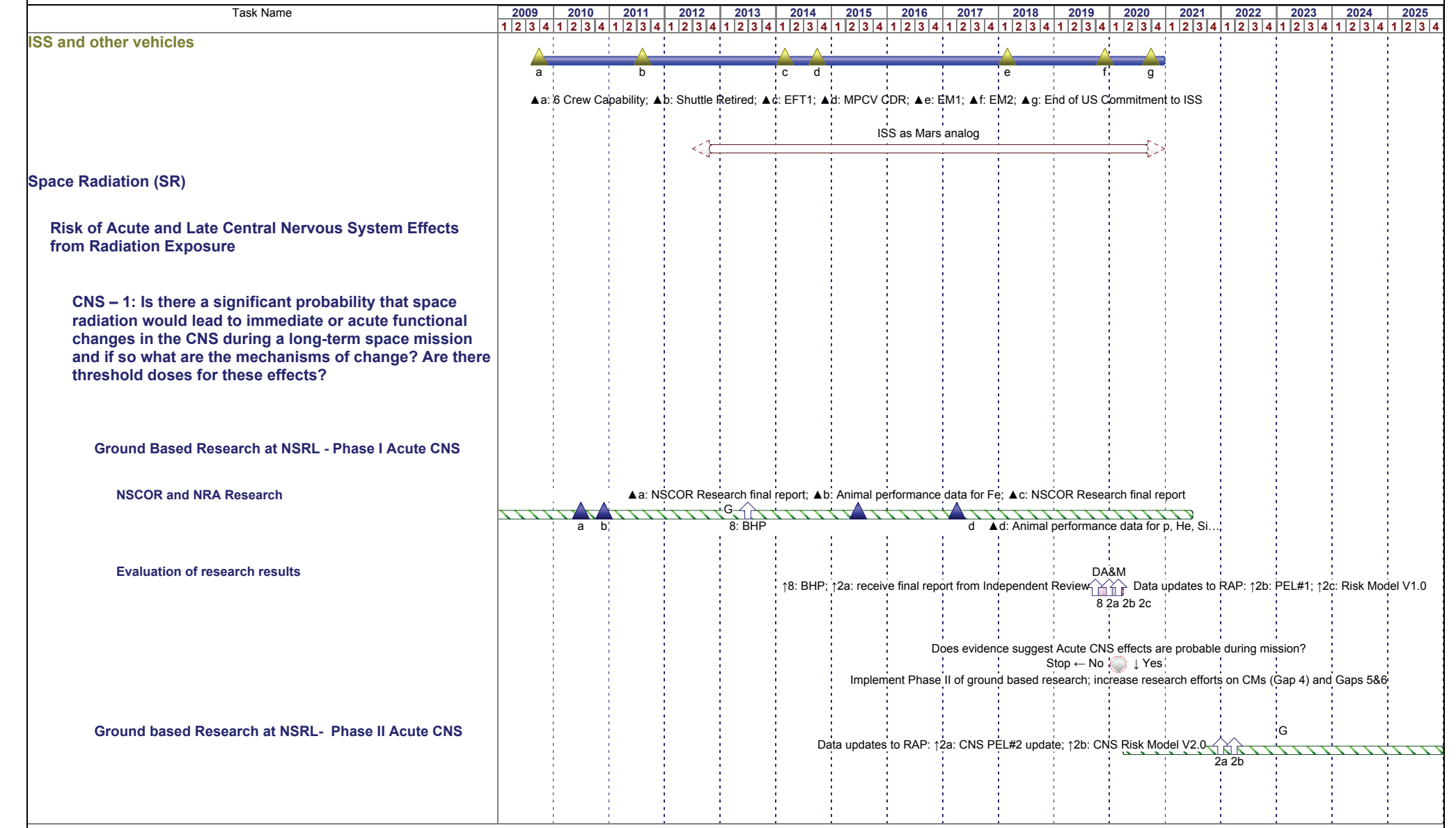
▲a: 6 Crew Capability; ▲b: Shuttle Retired; ▲c: EFT1; ▲d: MPCV CDR; ▲e: EM1; ▲f: EM2; ▲g: End of US Commitment to ISS
ISS as Mars analog
Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
Integration of Research Results
CNS Risk Projections: CNS Risk Model Development V1 and CNS PEL# 1 Update
Integration of Research Results from Gaps
G
Full description of model with supporting research report
Independent review of acute and late CNS research results including NSCOR, NRA and DOE Low Dose
DA&M
Final Report (Information to Gaps 1 & 2)
Updates to CNS PELs
DA&M
4
Recommended CNS PEL#1 updates
Does evidence suggest updates to CNS PELs are necessary? Is there sufficient data to proceed with risk model development?
Recommend PEL update. Proceed with model development. ↓ Yes
No → continue gap research
CNS Model updates/Final Verification
DA&M
CNS risk model V1 beta release
Baseline CNS Risk Model V1.0
5
CNS Risk Projections: CNS Risk Model V2.0 and CNS PEL#2 Update
Integration of Research Results from Gaps
G
Full description of model with supportin
Independent Review (includes synergies with other spaceflig
DA&M
Final Report
Updates to CNS PELs
↑2b: Information from Gap 8 synergies assessment in support of
Information from Gaps 1,2,3,5,6 in support of PEL#2 update
Recommeded CN
2a
DA&M
2b 4
Does evidence suggest updates to CNS PEL and Risk Model
Proceed with updates. Yes ↑
No → continue ga
CNS Model updates/Final Verification
DA&M
CNS Risk
5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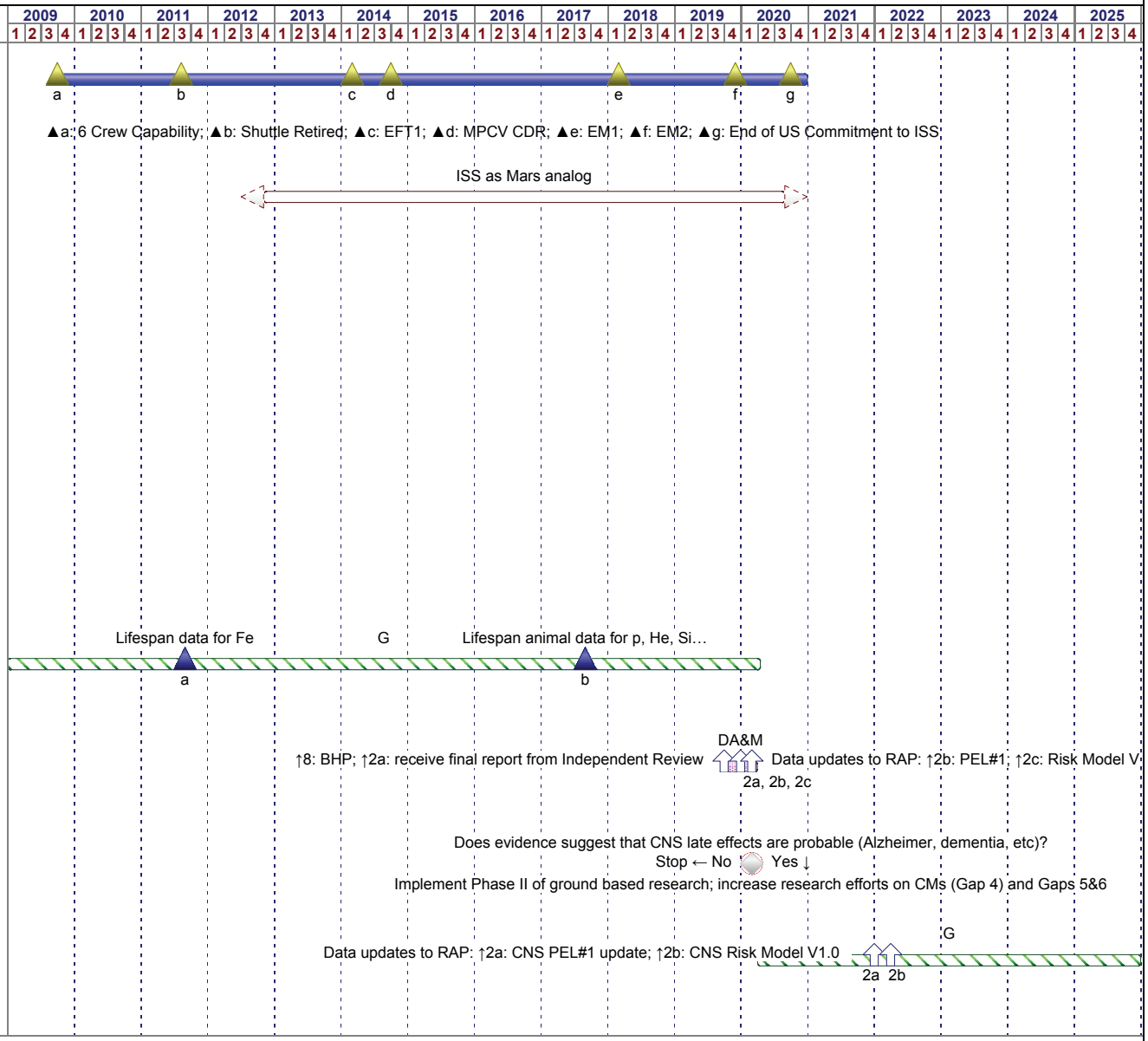
ISS as Mars analog
Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 1: Is there a significant probability that space radiation would lead to immediate or acute functional changes in the CNS during a long-term space mission and if so what are the mechanisms of change? Are there threshold doses for these effects?
Ground Based Research at NSRL - Phase I Acute CNS
NSCOR and NRA Research
▲a: NSCOR Research final report; ▲b: Animal performance data for Fe; ▲c: NSCOR Research final report
G
a b
8: BHP
d ▲d: Animal performance data for p, He, Si…
Evaluation of research results
DA&M
↑8: BHP; ↑2a: receive final report from Independent Review
Data updates to RAP: ↑2b: PEL#1; ↑2c: Risk Model V1.0
8 2a 2b 2c
Does evidence suggest Acute CNS effects are probable during mission?
Stop ← No
↓ Yes
Implement Phase II of ground based research; increase research efforts on CMs (Gap 4) and Gaps 5&6
Ground based Research at NSRL- Phase II Acute CNS
G
Data updates to RAP: ↑2a: CNS PEL#2 update; ↑2b: CNS Risk Model V2.0
2a 2b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Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 2: Is there a significant probability that space radiation exposures would lead to long-term or late degenerative CNS risks if so what are the mechanisms of change?
Ground Based Research to determine probability and mechanisms of late degenerative changes - Phase I Late CNS
NRA and DOE Low Dose Rate Research
Lifespan data for Fe
G
Lifespan animal data for p, He, Si…
a
b
Evaluation of Research Results
DA&M
↑8: BHP; ↑2a: receive final report from Independent Review
Data updates to RAP: ↑2b: PEL#1; ↑2c: Risk Model V
2a, 2b, 2c
Does evidence suggest that CNS late effects are probable (Alzheimer, dementia, etc)?
Stop ← No
Yes ↓
Implement Phase II of ground based research; increase research efforts on CMs (Gap 4) and Gaps 5&6
Ground Based Research to determine probability and mechanisms of late degenerative changes - Phase II Late CNS
G
Data updates to RAP: ↑2a: CNS PEL#1 update; ↑2b: CNS Risk Model V1.0
2a 2b

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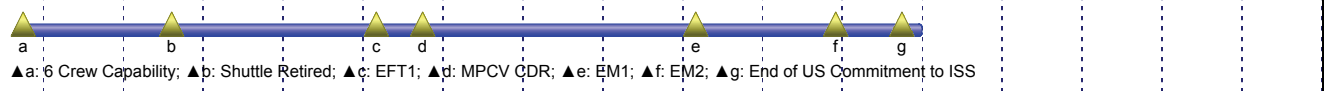
ISS and other vehicles



ISS as Mars analog

Space Radiation (SR)

Risk of Acute and Late Central Nervous System Effects from Radiation Exposure

CNS – 3: How does individual susceptibility including hereditary pre-disposition (Alzheimer's, Parkinson's, apoE) and prior CNS injury (concussion or other) alter significant CNS risks? Does individual susceptibility modify possible threshold doses?

Ground Based Research on individual susceptibility to CNS risks

G

↑2: Data updates to RAP: PEL#1

2

DA&M

↑2: Data updates to RAP: PEL#2

2

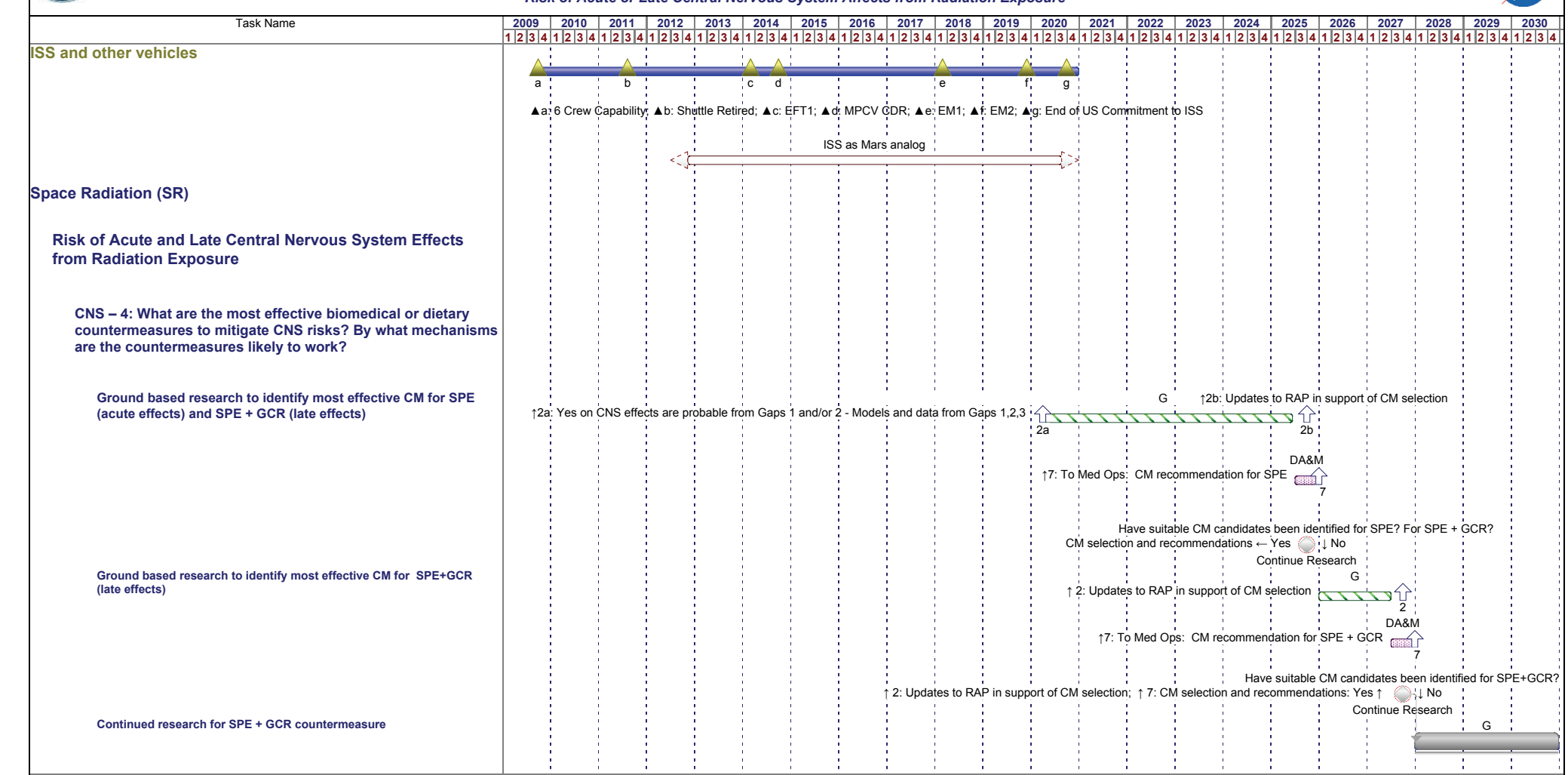
Does evidence suggest individual sensitivity is major factor?

Stop ← No Yes ↓

Proceed with clinical Study in Astronauts. Continue ground research Gaps 5 & 6

Clinical Study and Research

G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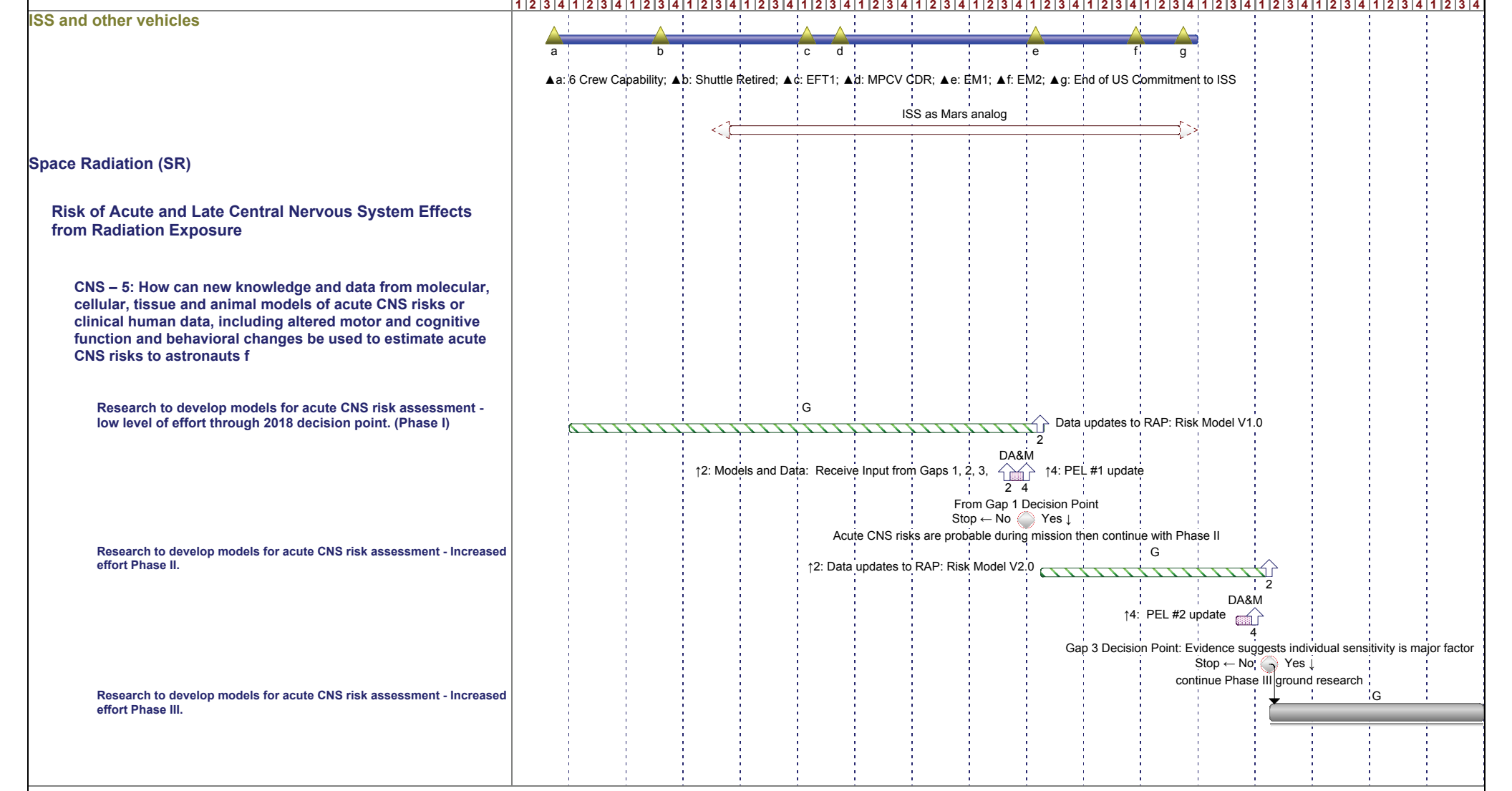
Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 4: What are the most effective biomedical or dietary countermeasures to mitigate CNS risks? By what mechanisms are the countermeasures likely to work?
Ground based research to identify most effective CM for SPE (acute effects) and SPE + GCR (late effects)
↑2a: Yes on CNS effects are probable from Gaps 1 and/or 2 - Models and data from Gaps 1,2,3
G
2a
↑2b: Updates to RAP in support of CM selection
2b
DA&M
↑7: To Med Ops: CM recommendation for SPE
7
Have suitable CM candidates been identified for SPE? For SPE + GCR?
CM selection and recommendations ← Yes
↓ No
Continue Research
Ground based research to identify most effective CM for SPE+GCR (late effects)
G
↑ 2: Updates to RAP in support of CM selection
2
DA&M
↑7: To Med Ops: CM recommendation for SPE + GCR
7
Have suitable CM candidates been identified for SPE+GCR?
↑ 2: Updates to RAP in support of CM selection; ↑ 7: CM selection and recommendations: Yes ↑
↓ No
Continue Research
Continued research for SPE + GCR countermeasure
G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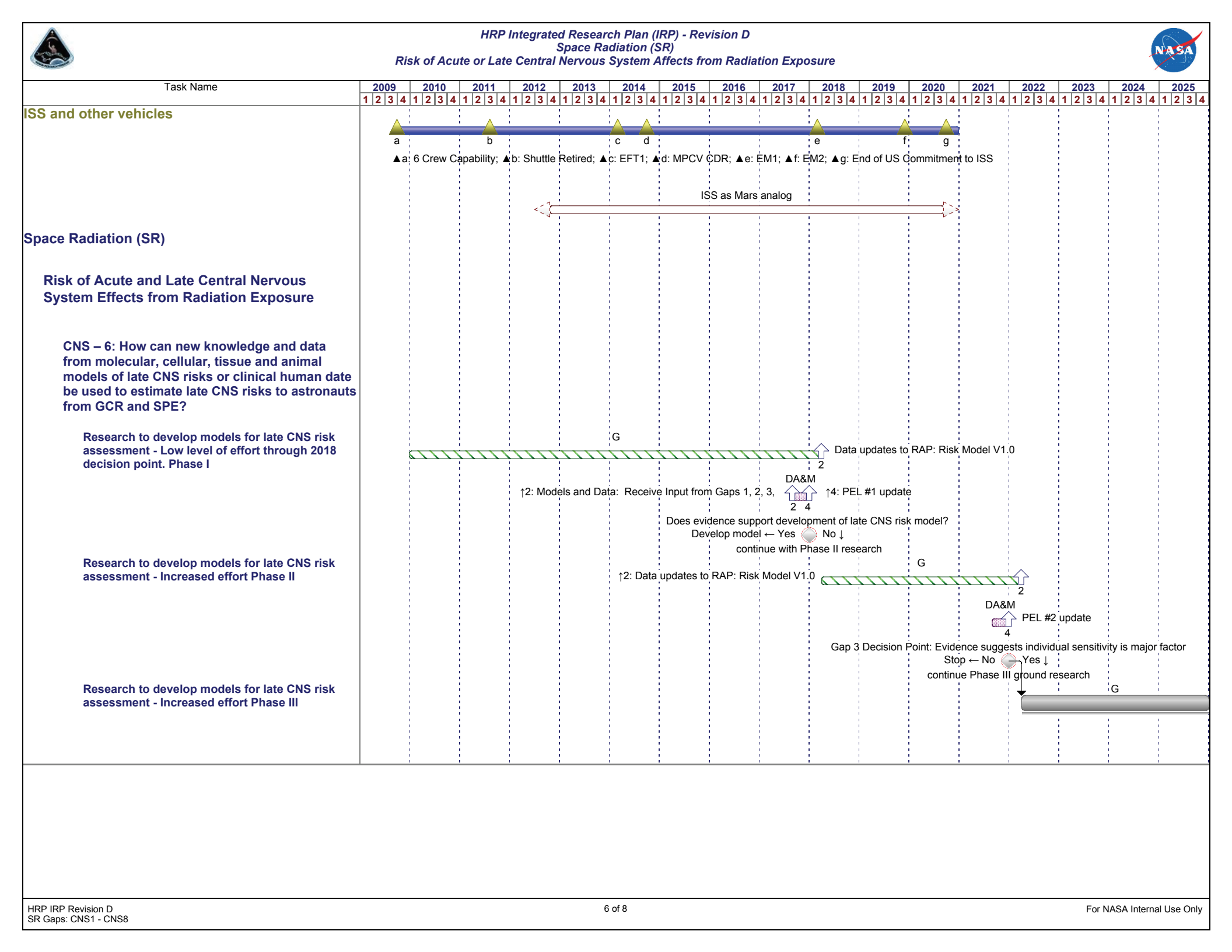
Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 5: How can new knowledge and data from molecular, cellular, tissue and animal models of acute CNS risks or clinical human data, including altered motor and cognitive function and behavioral changes be used to estimate acute CNS risks to astronauts f
Research to develop models for acute CNS risk assessment - low level of effort through 2018 decision point. (Phase I)
G
Data updates to RAP: Risk Model V1.0
2
DA&M
↑2: Models and Data: Receive Input from Gaps 1, 2, 3,
↑4: PEL #1 update
2 4
From Gap 1 Decision Point
Stop ← No
Yes ↓
Acute CNS risks are probable during mission then continue with Phase II
Research to develop models for acute CNS risk assessment - Increased effort Phase II.
G
↑2: Data updates to RAP: Risk Model V2.0
2
DA&M
↑4: PEL #2 update
4
Gap 3 Decision Point: Evidence suggests individual sensitivity is major factor
Stop ← No
Yes ↓
continue Phase III ground research
Research to develop models for acute CNS risk assessment - Increased effort Phase III.
G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Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 6: How can new knowledge and data from molecular, cellular, tissue and animal models of late CNS risks or clinical human date be used to estimate late CNS risks to astronauts from GCR and SPE?
Research to develop models for late CNS risk assessment - Low level of effort through 2018 decision point. Phase I
G
Data updates to RAP: Risk Model V1.0
2
DA&M
↑2: Models and Data: Receive Input from Gaps 1, 2, 3,
↑4: PEL #1 update
2 4
Does evidence support development of late CNS risk model?
Develop model ← Yes
No ↓
continue with Phase II research
Research to develop models for late CNS risk assessment - Increased effort Phase II
G
↑2: Data updates to RAP: Risk Model V1.0
2
DA&M
PEL #2 update
4
Gap 3 Decision Point: Evidence suggests individual sensitivity is major factor
Stop ← No
Yes ↓
continue Phase III ground research
Research to develop models for late CNS risk assessment - Increased effort Phase III
G

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ISS and other vehicles

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ISS as Mars analog

Space Radiation (SR)

Risk of Acute and Late Central Nervous System Effects from Radiation Exposure

CNS – 7: What are the best shielding approaches to protect against CNS risks, and are shielding approaches for CNS and cancer risks synergistic?

Develop Systems Biology Model to interpolate on ion type, rate, and crew factors

Late CNS risks are probable. ↓2a: Yes from Gap 2 If No → Stop

Individual ussceptibility risks are probable? ↓2b: Yes from Gap 3 decision point

System biology models to assess late CNS risks

G

2a

Inclusion of individual susceptibility factors

G

2b

Shielding Assessment for CNS

DA&M

↑5: Informing Mission Ops: CNS shielding assessment

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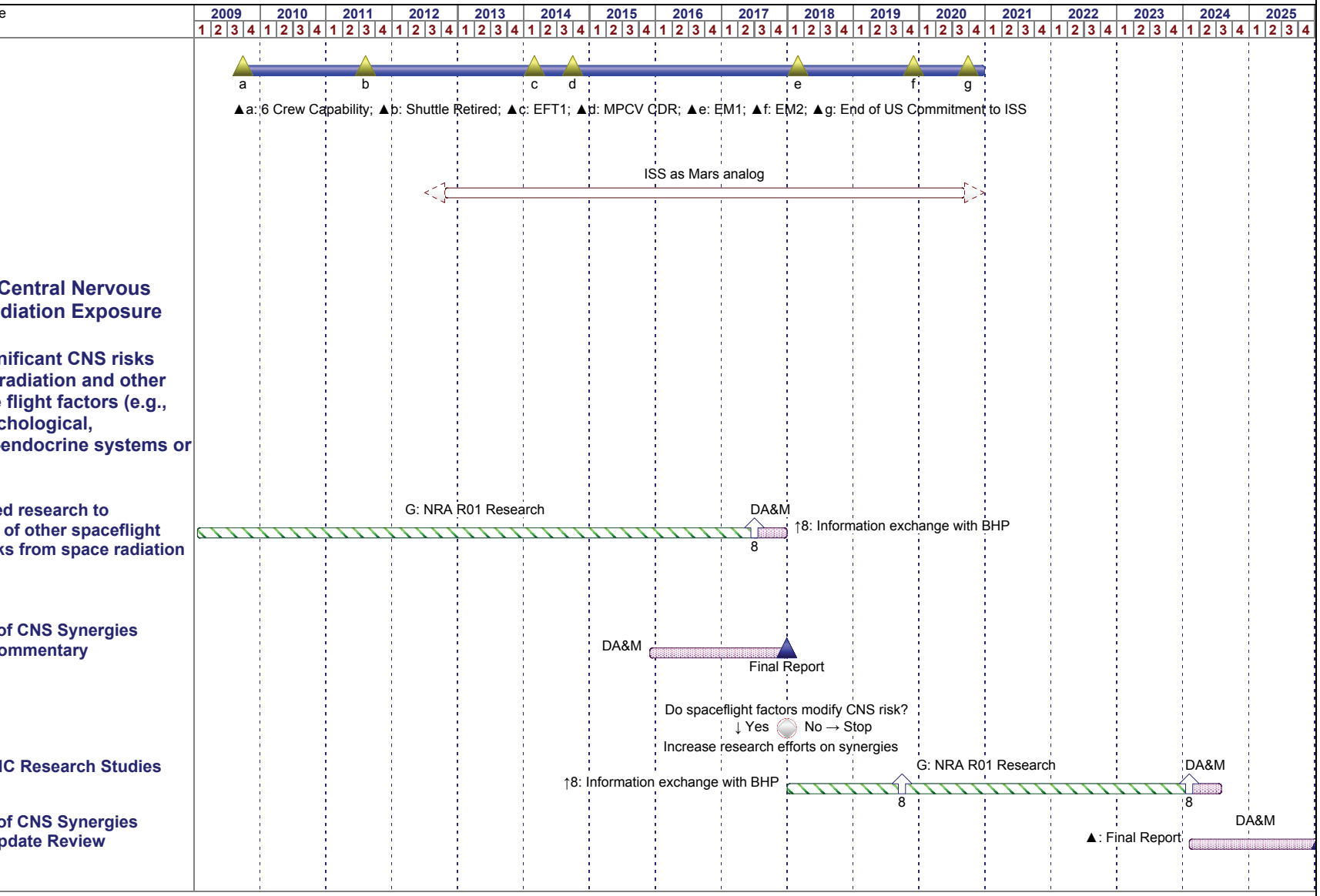
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Space Radiation (SR)
Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
CNS – 8: Are there significant CNS risks from combined space radiation and other physiological or space flight factors (e.g., sleep deprivation, psychological, microgravity, immune-endocrine systems or other)?
Conduct ground based research to understand influence of other spaceflight stressors on CNS risks from space radiation exposure
G: NRA R01 Research
DA&M
↑8: Information exchange with BHP
8
Independent Review of CNS Synergies Assessment NCRP Commentary
DA&M
Final Report
Do spaceflight factors modify CNS risk?
↓ Yes
No → Stop
Increase research efforts on synergies
Combined SR and HHC Research Studies
↑8: Information exchange with BHP
G: NRA R01 Research
DA&M
8
8
Independent Review of CNS Synergies Assessment NCRP Update Review
DA&M
▲: Final Report