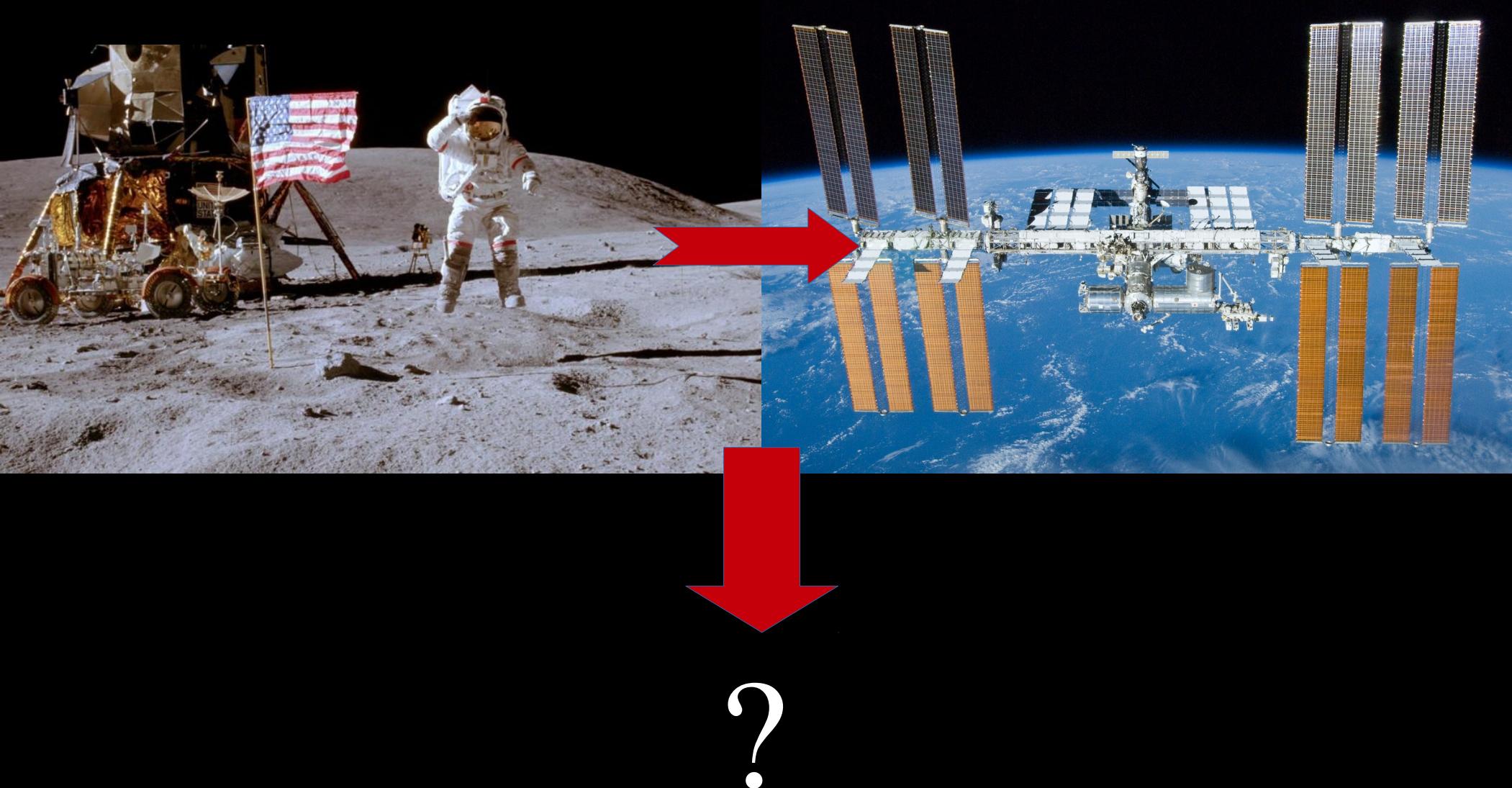


L'Humain dans l'espace

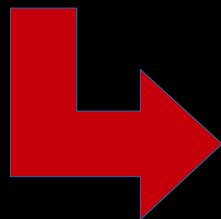


Pourquoi ne sommes-nous pas partis plus loin ?



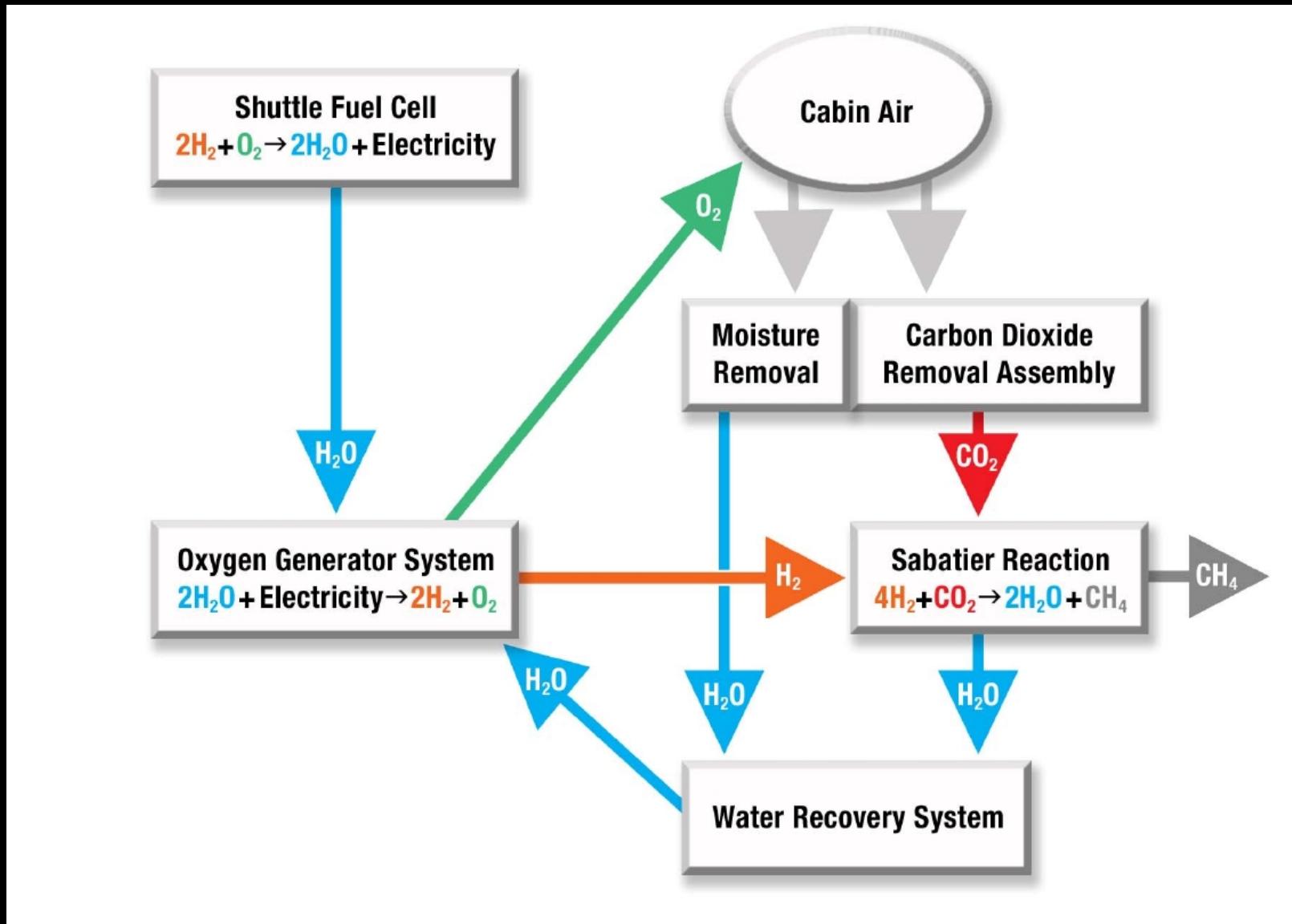
Supposons :

- **Crédits illimités**
- **Des fusées suffisamment puissantes**
- **Des moteurs performants**
- **Que chaque mission admette un retour**

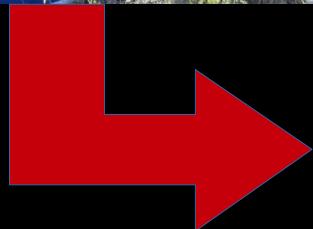


Conquête spatiale

Recyclage de l'air et de l'eau



L'état impesanteur



- Mal de l'espace
- Problèmes osseux
- Problèmes musculaires
- Difficultés respiratoires
- Problèmes d'équilibre



Nasa Human Research Program

Figure 1: Human Health and Performance Risks by Space Environment Hazard

Altered Gravity Field

1. Vision Impairments and Intracranial Pressure (VIIP)
2. Renal Stone Formation
3. Sensorimotor Alterations
4. Bone Fracture
5. Reduced Muscle Mass, Strength, and Endurance
6. Reduce Aerobic Capacity
7. Host-Microorganism Interactions
8. Cardiac Rhythm Problems
9. Orthostatic Intolerance
10. Intervertebral Disc Damage^a
11. Space Adaptation Back Pain
12. Urinary Retention
13. Pharmacokinetics^{a, b}

Radiation

14. Space Radiation Exposure

Distance from Earth

15. Adverse Outcomes due to Inflight Medical Conditions
16. Uneffective or Unpredictable Effects of Medication Due to Storage

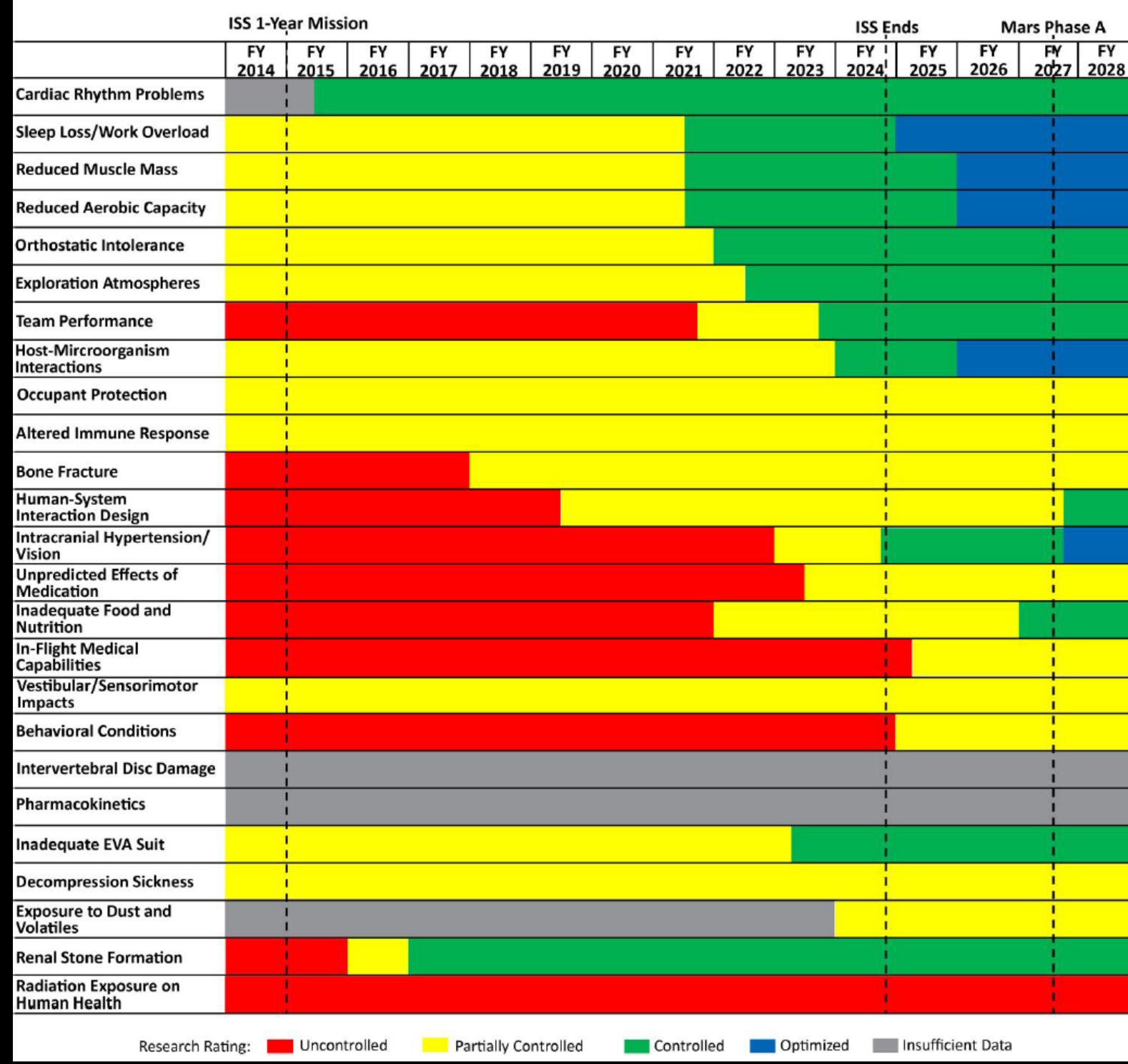
Hostile/Closed Environment Space Craft Design

17. Inadequate Food and Nutrition
18. Inadequate Human-System Interaction Design
19. Injury from Dynamic Loads (Occupant Protection)
20. Injury and Compromised Performance Due to EVA Operations
21. Celestial Dust Exposure
22. Altered Immune Response
23. Exploration Atmospheres
24. Sleep Loss, Circadian Desynchronization, and Work Overload
25. Toxic Exposure
26. Decompression Sickness
27. Hearing Loss Related to Spaceflight
28. Acute and Chronic Carbon Dioxide Exposure
29. Injury from Sunlight Exposure
30. Electrical Shock^c

Isolation

31. Adverse Cognitive or Behavioral Conditions
32. Inadequate Team Performance

Figure 3: HRP Path to Risk Reduction for a Planetary Mission



Source: HSRB, June 2015, PRR Revision C.

17: Inadequate Food and nutrition

Table 4: Inadequate Food and Nutrition In-Mission and Post-Mission Risk

		Low Earth Orbit (6 months)	Low Earth Orbit (1 year)	Lunar Visit (1 year)	Asteroid (1 year)	Planetary (3 years)
Inadequate Food and Nutrition	In-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation

Source: Human System Risks Summary Charts, HMTA, January 2015.

Legend: High consequences Low to medium consequences Very low to low consequences



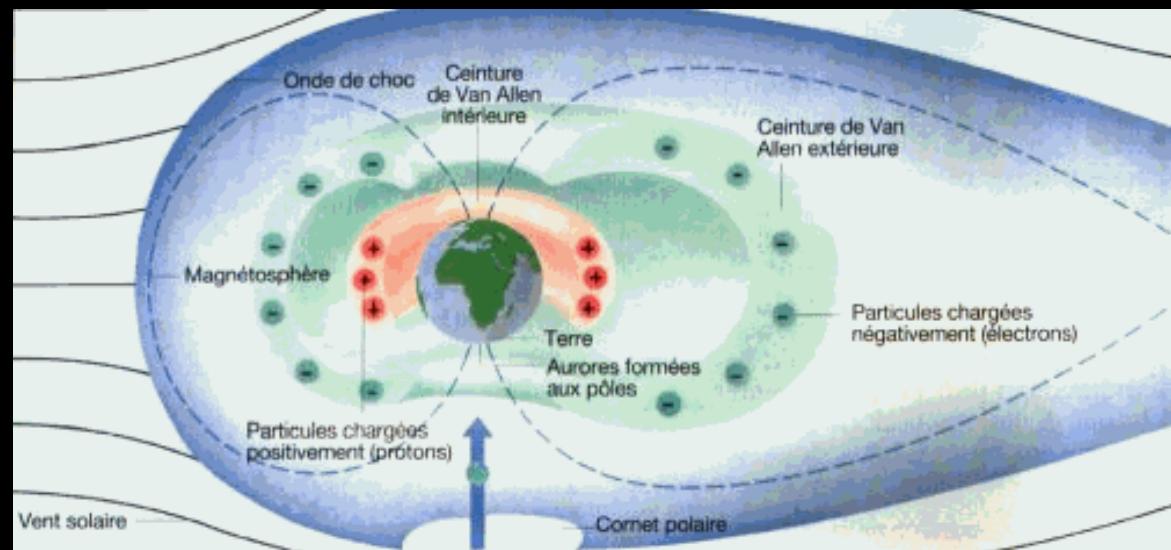
14 : Space Radiation Exposure

Table 5: Space Radiation Exposure In-Mission and Post-Mission Risk

		Low Earth Orbit (6 months)	Low Earth Orbit (1 year)	Lunar Visit (1 year)	Asteroid (1 year)	Planetary (3 years)
Space Radiation Exposure	In-Mission Risk	Accepted	Accepted	Accepted	Accepted	Accepted
	Post-Mission Risk	Accepted	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation

Source: Human System Risks Summary Charts, HMTA, January 2015.

Legend: High consequences Low to medium consequences Very low to low consequences

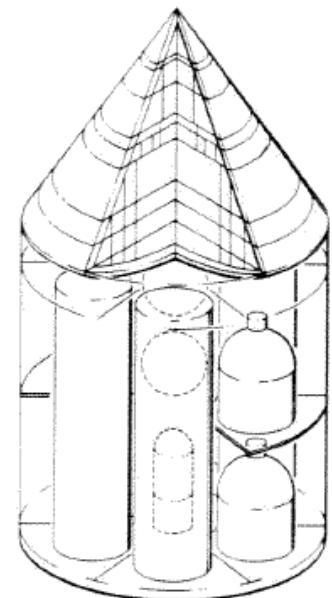


Hypothèses:

- Volumes discrets
- 369 régions
- 15 matériaux

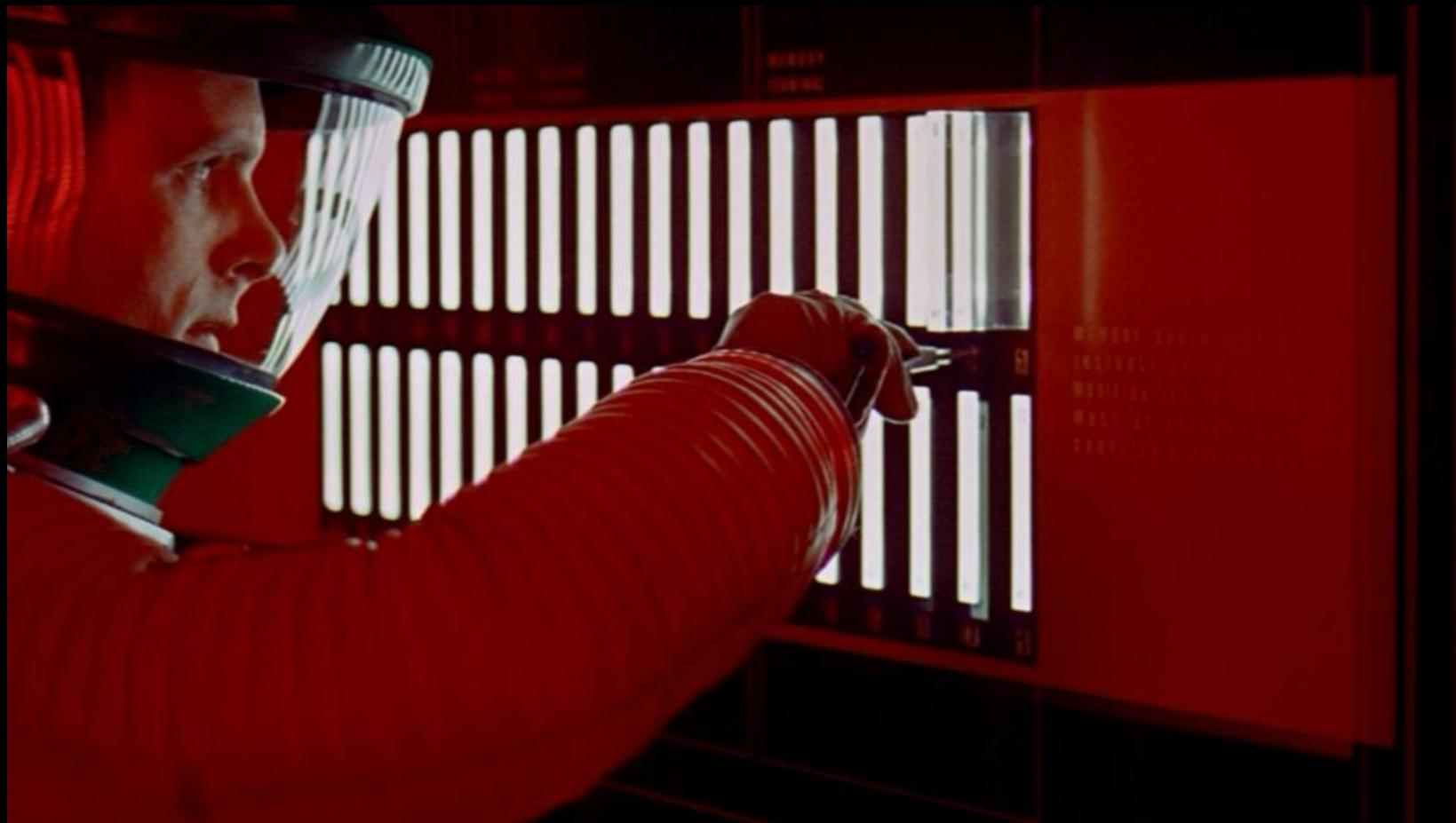
Calculs:

- Gamme d'énergie par matériau
- Dose à un point quelconque
- Dose au volume
- Dose secondaire



Répartition des zones dans le CSM Apollo

18 : Inadequate human-system interaction design



Problèmes comportementaux

Table 3: Behavioral Health and Performance In-Mission and Post-Mission Risks

		Low Earth Orbit (6 months)	Low Earth Orbit (1 year)	Lunar Visit (1 year)	Asteroid (1 year)	Planetary (3 years)
Cognitive or Behavioral Conditions	In-Mission Risk	Accepted	Requires Mitigation	Requires Mitigation	Requires Mitigation	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
Sleep Loss	In-Mission Risk	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Requires Mitigation	Requires Mitigation
Team Performance	In-Mission Risk	Accepted	Accepted	Accepted	Accepted	Requires Mitigation
	Post-Mission Risk	Accepted	Accepted	Accepted	Accepted	Accepted

Source: Human System Risks Summary Charts, HMTA, January 2015.

Legend: High consequences Low to medium consequences Very low to low consequences



Human Research Program

Integrated Path to Risk Reduction, Revision C (2015)

		FY14	FY15	FY16	FY17	FY18	FY19	FY20	FY21	FY22	FY23	FY24	FY25	FY26	FY27	FY28		
Planetary DRM (Mars) Risks	LxC	ISS I-YR Mission	Asteroid Phase A	CCP	EM-1	ARRM	EM-2				ISS End	ARCM	Mars Phase A					
Cardiac Rhythm Problems (Arrhythmia)	3x4			Risk Understood														
Sleep Loss/Work Overload (Sleep)	3x3			Key Monitoring Tools Developed and Validated			Risk Understood			Key CMs Individualized and Validated		Integrated Monitoring Tools and CMs Validated						
Reduced Muscle Mass (Muscle)	3x3			Standard Updated			Standard Validated			Inflight CM Validated Current Hardware		Inflight CM Validated Exploration Hardware						
Reduced Aerobic Capacity (Aerobic)	3x3			Standard Updated			Standard Validated			Inflight CM Validated Current Hardware		Inflight CM Validated Exploration Hardware						
Orthostatic Intolerance (OI)	3x2						In-/Post-flight CM Validated											
Exploration Atmospheres (ExAtm)	3x3			Short Duration Interim Review			Short term Chamber Eval Down-select			Risk Characterized								
Team Performance (Team)	3x4						Risk Understood		Stds Dev / Meas Dev & Val		CMS Developed and Validated							
Host-Microorganism Interactions (Microhost)	3x3						AEH-12 Risk Understood		AEH10 & 13 Risk Understood		AEH10 Risk Understood; Probiotic CM developed		Virulence CM Dev.					
Occupant Protection (OP)	3x3			Standards Updated			Validated Analytical Tool			Risk Characterized, Standards Updated								
Altered Immune Response (Immune)	3x3						Altered immune response clinically significant?		Analog Identified		Risk Characterized / CM needed?			Inflight CM Validated				
Bone Fracture (Fracture)	2x4			Updated Bone Std.			Risk Characterized, Treatment Validtd			Risk Quantification Updated		Treatment Validated						
Human-System Interaction Design (HSID)	3x4						HARI Risk Understood		TRAIN Risk Understood		NHV Val		TASK CM Validated	HCI CM Validated	TRAIN CM Identified	HARI CM Validated		
Intracranial Hypertension/Vision (VIIP)	3x4									Eye etiology; correlated cognition function		Risk Understood/ Potential CMs Identified		CMs Validated	CMs Optimized			
Unpredicted Effects of Medication (Stability)	3x4			Most Com'n Usage Detrm'd					Stability Risk Determinants Gmd Stability Testing Comp		TRO Validated Stability Dev		Med Usage Understd Pkg Sys Validtd					
Inadequate Food and Nutrition (Food)	3x4						Potential Nutritional CM Identified		Food System Reqs to AFT		Nutrition CMs Aft & S Risk's Validated		Food System Reqs to AFT	Req. & Tool Vldt.	Nutr CMs Optimized			
In-Flight Medical Capabilities (ExMC)	3x4			EMSD			FUS		ELA		OCM		Med Suction		MSK	Sterile	Risk Mitigation Assessment	
Vestibular/Sensorimotor Impacts (Sensorimotor)	3x3						Standard Update			Risk Understood			CMS Developed, Standard Validated				Inflight CMs Validated	
Behavioral Conditions (BMed)	3x4									Risk Factors Understood			Monitoring Tools Developed		CMS & Treatment Developed			
Intervertebral Disk Damage (IVD)																		
Pharmacokinetics (PK/PD)																		
Inadequate EVA Suit (EVA)	3x3																	
Decompression Sickness (DCS)	3x3																	
Exposure to Dust & Volatiles (Dust)																		
Renal Stone Formation (Renal)	3x4																	
Radiation Exposure on Human Health	3x4																	



ISS Required



ISS Not Required



Milestones Requires ISS



Milestone Shift

■ Uncontrolled
■ Partially Controlled
■ Controlled
■ Optimized
■ Insufficient Data

Assumptions:

- 450 crew hrs/ increment pair
- 3 crew/ increment pair
- 6 month missions

Updated
6/10/15

HRPCB-approved
PPBE17 baseline

Conclusion

