



**MOON 2020-2030**

A new era of human and robotic exploration

# **HERACLES: A POSSIBLE EML2-BASED HUMAN-ROBOTIC ARCHITECTURE WITH NEAR-TERM LUNAR SURFACE EXPLORATION OBJECTIVES**

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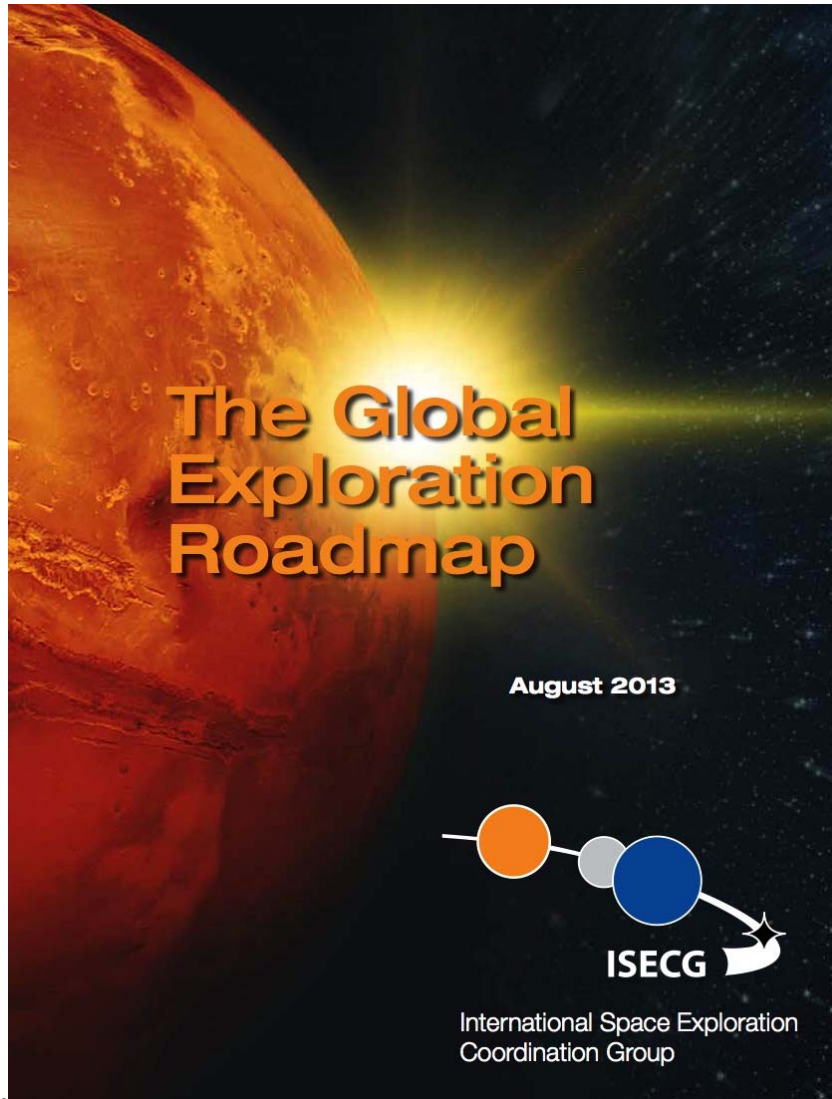
European Space Agency

ESA/ESTEC Noordwijk

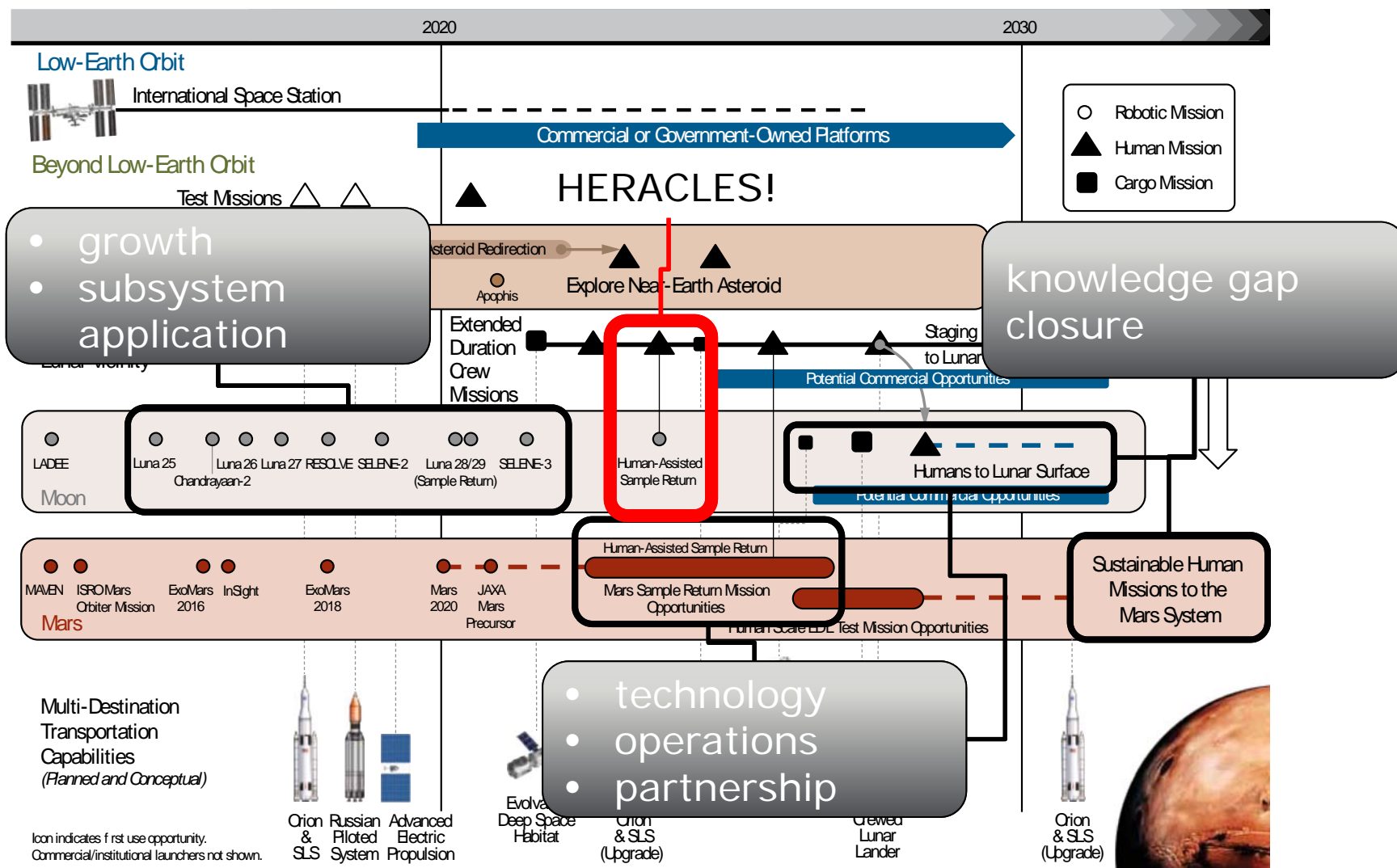
15-16 December 2015

European Space Agency

# STRATEGIES CALL FOR IMPLEMENTATION



# IMPLEMENTING GLOBAL EXPLORATION



# HERACLES SCENARIO



WSB

NRO

WSB Transfer

ground control

crew control

Lunar Gravity Assist

LLO

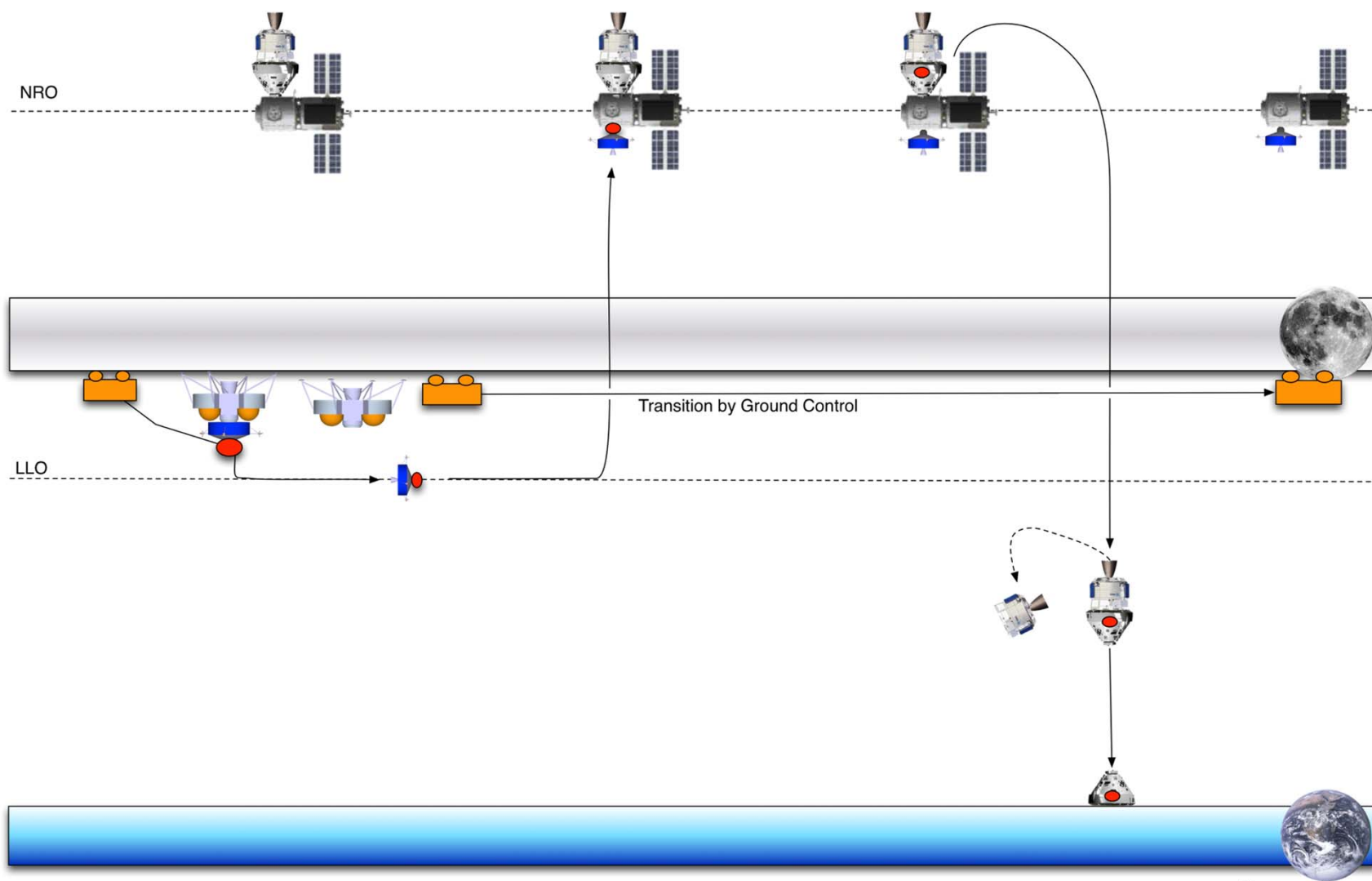
GTO

wet LDE: 8.7t  
wet LAE: 1.3t  
SME: 0.5t  
Adapter: 0.5t

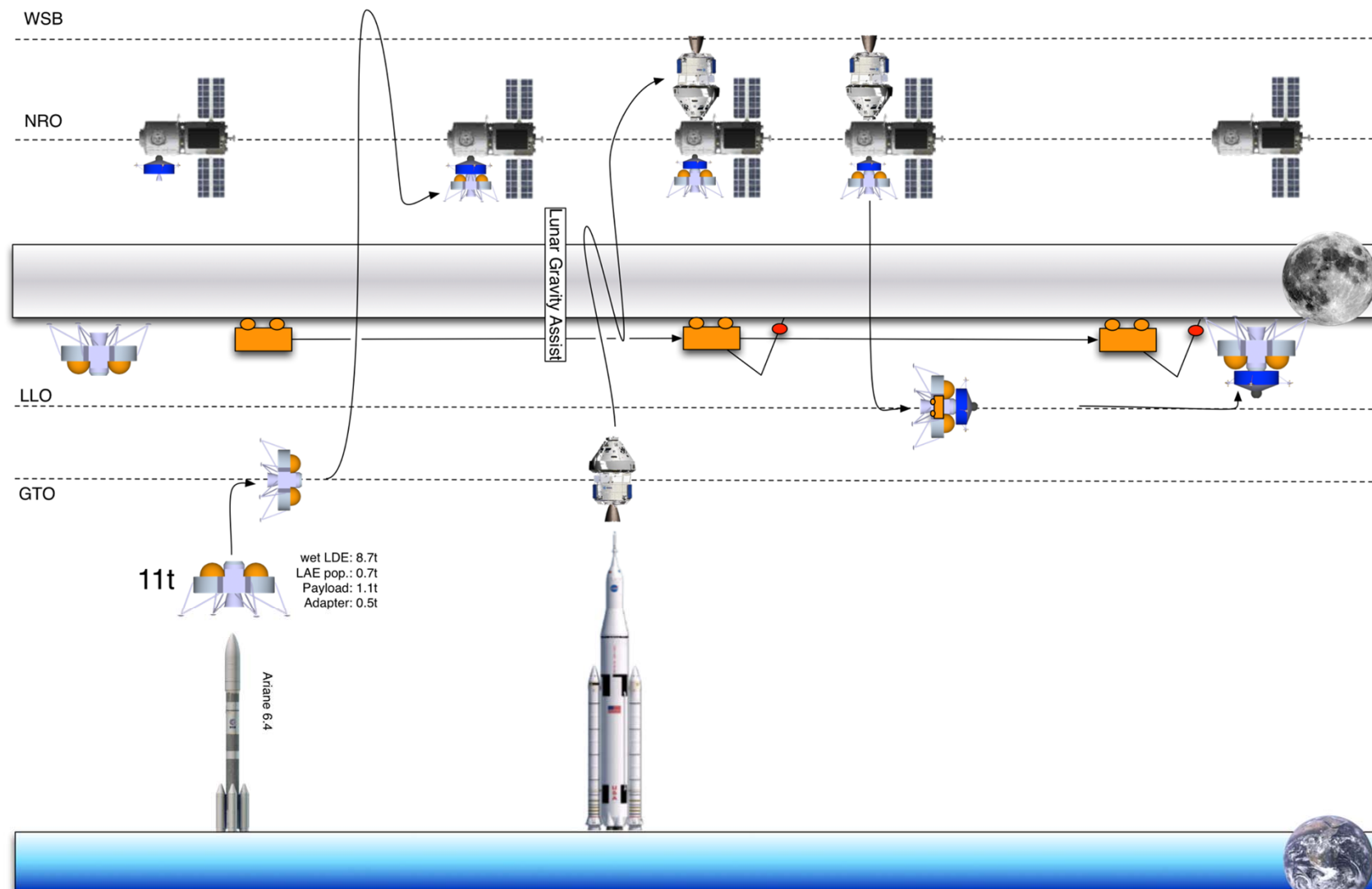
11t

Ariane 64

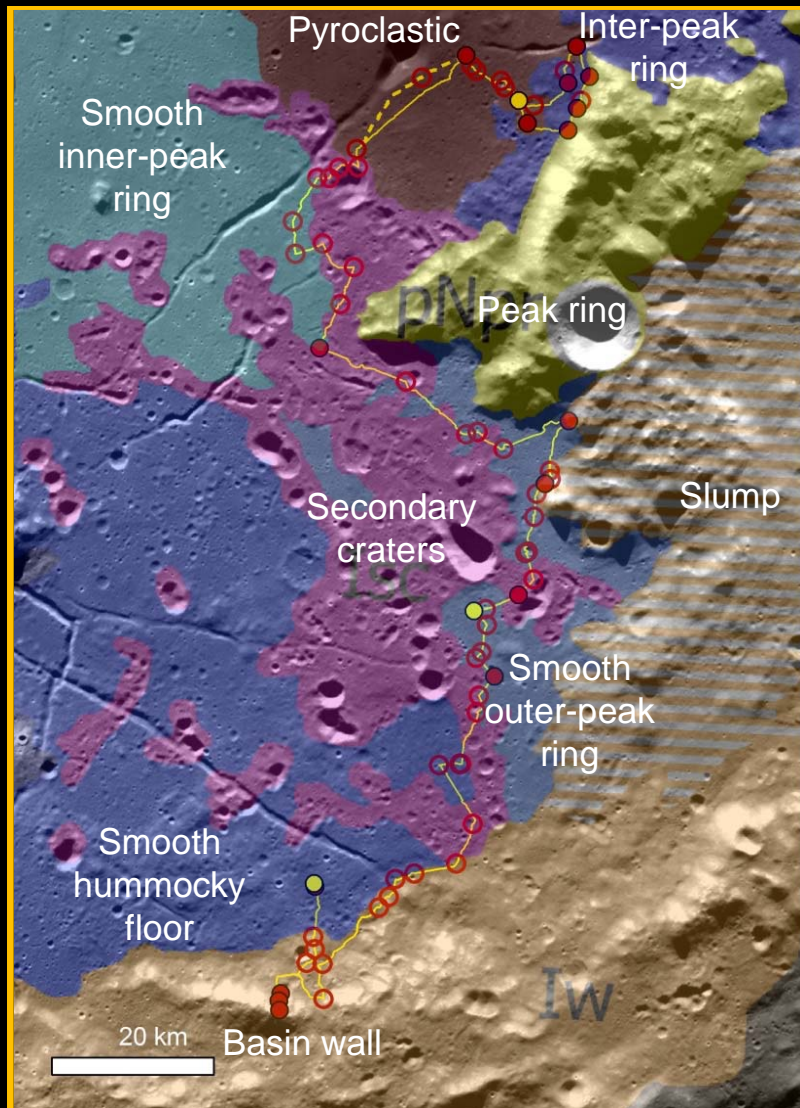
# HERACLES SCENARIO



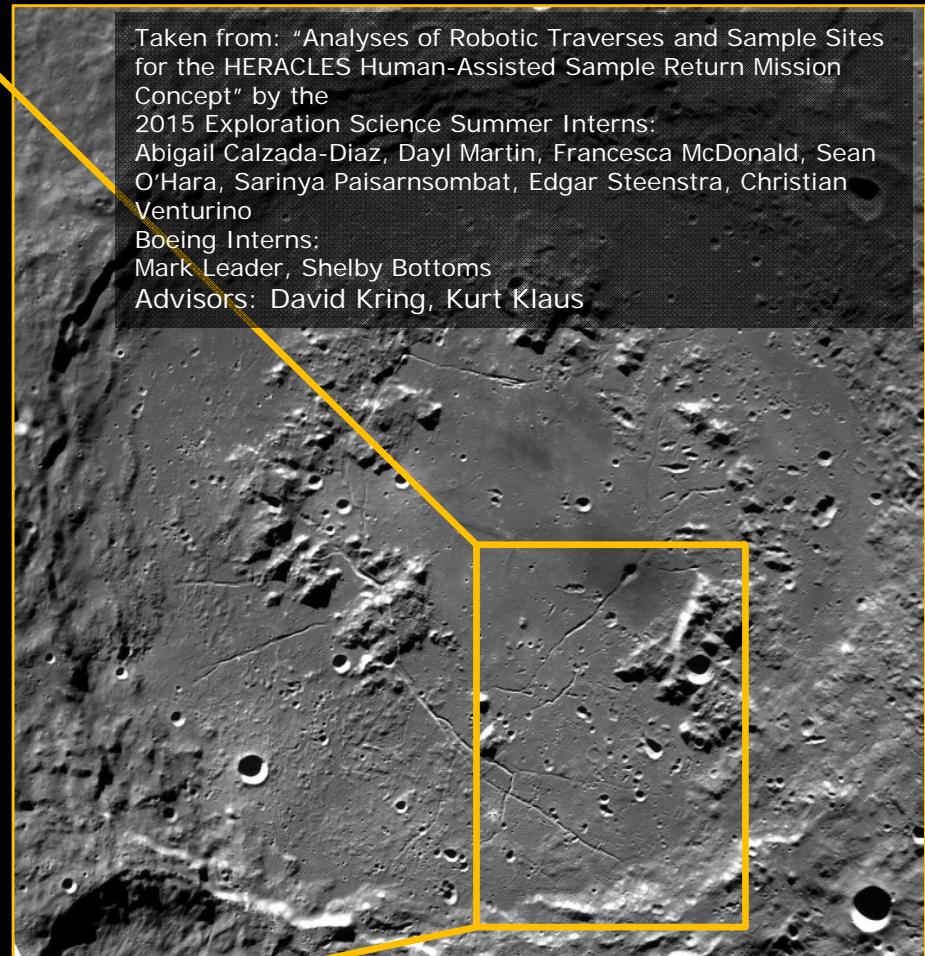
# HERACLES SCENARIO



# SURFACE OPERATIONS AND CAMPAIGN



Taken from: "Analyses of Robotic Traverses and Sample Sites for the HERACLES Human-Assisted Sample Return Mission Concept" by the 2015 Exploration Science Summer Interns: Abigail Calzada-Diaz, Dayl Martin, Francesca McDonald, Sean O'Hara, Sarinya Paisarnsombat, Edgar Steenstra, Christian Venturino  
Boeing Interns: Mark Leader, Shelby Bottoms  
Advisors: David Kring, Kurt Klaus



# SCIENCE OPPORTUNITIES



NRC Concept/Goal	a	b	c	d	e
1: Bombardment history of the inner solar system	<i>Test cataclysm hypothesis</i>	<i>Age of South Pole-Aitken basin</i>	<i>Establish absolute chronology</i>	Recent impact flux	Secondary craters
2: Structure and composition of lunar interior	<i>Thickness/variability of lunar crust</i>	<i>Stratification of mantle</i>	<i>Size, composition, state of core</i>	Thermal state of interior	N/A
3: Diversity of lunar crustal rocks	<i>Differentiation products</i>	<i>Age, distribution, origin of rocks</i>	Composition of lower crust	Complexity of lunar crust	Extent/structure of megaregolith
4: Lunar poles and volatiles	<i>State and distribution of volatiles</i>	Source of volatiles	Transport, alteration, loss processes	Properties of polar regolith	Polar regolith and ancient solar environment
5: Lunar volcanism	Origin/variability of basalts	Age of mare basalts	Range/extent of pyroclastic deposits	Lunar volcanic flux	N/A
6: Impact processes	Melt sheet differentiation	Structure of multi-ring impact basins	Crater formation	Mixing of local and ejecta material	N/A
7: Regolith processes	Characterize ancient regolith	Physical properties of regolith	Regolith modification processes	Rare minerals in regolith	N/A

*Bold-italic goals are ranked as high priority*

Addressed along traverse
  Not addressed along traverse
  May be addressed along traverse

# WHY TELE-ROBOTIC OPERATIONS?



- Driven by preparation of human exploration operations
- Previous experience (Lunakhod) exists within international partnership
- Higher performance for complex operations
- Planned/on-going tests determine control efficiency
  - driving
  - sampling
  - landing

# WHY REUSABILITY?



Item	Mass [kg]	Complexity factor
Ascent stage	621	419
Descent stage	1442	173
Rover	539	446



# BENEFITS



- Lower cost if multiple missions are employed
- Flight-testing of key subsystems critical for human capability
- High level of similarity to human mission
- Preparation of partner roles in lunar exploration
- Growth path for key architecture elements
- Mature end-to-end sample handling chain for MSR
- High-performance mobility
- Most high-priority science goals addressed
- Science opportunities beyond lunar science
- Opportunity for mitigating the dust risk for human mission

# "FIRST"



- First soft landing south of  $41^{\circ}\text{S}$
- First soft landing Pole-ward of  $45^{\circ}$  latitude
- First return of samples outside the KREEP region
- First landing on the far side
- First equipment surviving lunar night
- First Moon rover tele-operated by orbital crew
- First sample delivery to orbital station
- First assembly of Moon lander in orbit
- First return of SPA samples
- First return of PSR samples
- First cryogenic sample return
- First reuse of lunar ascent stage
- First rover to visit more than one landing sites
- First production of oxygen from lunar regolith
- First climb of lunar mountain by rover
- First lander tele-operated by orbital crew



THANK YOU

European Space Agency