Proposed Mars Astrobiology Explorer – Cacher (MAX-C) & ExoMars 2018 (MXM-2018) Mission Formulation Status

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(includes adaptations of slides from Charles Whetsel, Mike Wilson, Adam Steltzner, Tom Rivellini, Marguerite Syvertson)*

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Agenda

- Background and Formulation Status
- Top Level NASA and ESA Requirements
- Proposed MAX-C Rover Description
- ExoMars Rover Description
- Proposed Delivery System Description
- Summary

Mission Background

- Science objectives for NASA's proposed next generation Mars rover (MAX-C) have been maturing and solidifying over the last year
  - Mid-Range Rover Science Analysis Group report, commissioned by MEPAG submitted to NRC Planetary Science Decadal Survey "white-paper" process in the fall – **M**ars **A**strobiology E**x**plorer
  - Inclusion of **C**aching encapsulated rock cores together with *in situ* instrumentation for future return, would make this rover the first mission in a potential Mars Sample Return Campaign

- Additionally, NASA's joint Mars Exploration Initiative results in a set of cooperative ventures over the coming decade
  - ESA to provide orbiter bus in support of NASA's atmospheric science objectives in 2016
  - Future division of responsibilities and costs for ultimate Mars Sample Return campaign to be established in the near future

- The overall objectives of the proposed 2018 mission concept are:
  - Develop the proposed MAX-C Rover with *in situ* and caching payload, per MRR-SAG & Decadal Survey Guidance
  - Deliver both MAX-C and ExoMars Rovers to the surface of Mars

Formulation Status

- The strategy for delivering the proposed rovers to the Martian surface would be to inherit to the greatest extent possible from the MSL Cruise, Entry and Descent System.
  - Believed to minimize both mission and development risk.

- The current design maturity of the ExoMars Rover (previously planned for earlier launch) is considerably higher than that of the proposed MAX-C Rover.

- The primary focus of the study team has been on the physical accommodation of the two rovers, given
  - an understanding of what changes to ExoMars are and aren't perceived to be feasible at this time, and
  - what is deemed to be a reasonable resource envelope to accomplish the stated *in situ* and caching objectives of the proposed MAX-C Rover.

- A combination of Team X sessions and a dedicated pre-project design team have been used to advance the state of the design thus far.

- Conducted a Mars 2018 (MAX-C) Concept Feasibility Review on March 4, 2010.

Top Level Architectural Option Space

- **Airbag Lander (MPF/MER)**
- **Skycrane Lander (MSL)**
  - **Pallet**
  - Land on Wheels
    - Separate
      - Simultaneous (yoke)
      - Double-drop
    - Mother/Daughter
- **Legged Lander (Viking/Phoenix)**

We have drilled down to a design point on one particularly promising branch of the architectural option space to answer a question of feasibility ("existence proof").

We will now give other branches and sub-branches additional consideration (through ~CY2010), and then further trade and optimize the resulting baseline to simplify the system and balance risk (through ~CY2011).

NASA Program Level Functional Requirements (proposed)

- Launch to Mars in 2018 opportunity.
- Be capable of landing at altitudes up to [-1.0] km relative to the MOLA areoid.
- Be capable of landing and operating at sites between [25°N and 15°S] latitude.
- Be capable of landing with an error of [11] km or less radius from a designated point on the surface of Mars (excluding any uncontrolled effects of winds during parachute descent).
- Provide data communications throughout critical events, at a rate sufficient to determine the state of the spacecraft in support of fault reconstruction, to relay assets provided by the Mars Program or to the Deep Space Network.
- Deliver to Mars both the proposed MAX-C NASA Rover and the ExoMars ESA Rover.
- NASA Rover to have total traverse path length capability of at least [20] km.
- NASA Rover to conduct Mars surface sample selection and coring/caching operations for at least [500] sols.
- NASA Rover to be able to select, acquire, and cache at least [38] core samples ([2] caches of at least [19] cores each).

NASA Program Level Science Requirements (proposed)

- NASA Rover to carry instrumentation sufficient to scientifically select samples for caching.
  - It is assumed that this translates to the following measurements and possible strawman payload suite:
    - Must be able to remotely (i.e. with mast-mounted instruments) characterize outcrops and identify features of interest [note: Pancam, Near-IR Spectrometer]
    - Must be able to collect microscale imagery of outcrops; contact instrument [note: Microscopic Imager example]
    - Must be able to expose unweathered rock surfaces (i.e. using a surface abrasion tool with TBD characteristics) [note: Abrading Bit example, possible RAT or SRT equivalent]
    - Must be able to measure mineralogy at micro-scales (mm-cm) on the abraded rock surfaces; contact instrument [note: Raman example]
    - Must be able to measure bulk elemental chemistry on the abraded rock surfaces; contact instrument [note: APXS example]
    - Must be able to measure organic compounds at micro-scales (mm-cm) on the abraded rock surfaces; contact instrument [note: Raman example]
    - Must be able to correlate composition to micro-scale structures and textures in the rocks [note: Microscopic Imager example]
- Go to a site such that regions of scientific interest would be reachable within traverse capabilities of the rover.
  - At a high level it is assumed that this would dictate a capability to land at MSL-like sites in terms of rocks and slopes in order to put targets within reach.
    - Must be able to land at sites with [99%] areal density of up to [60 cm] rocks and [99%] areal density of up to [22.5°] slopes at scales of the landed system.

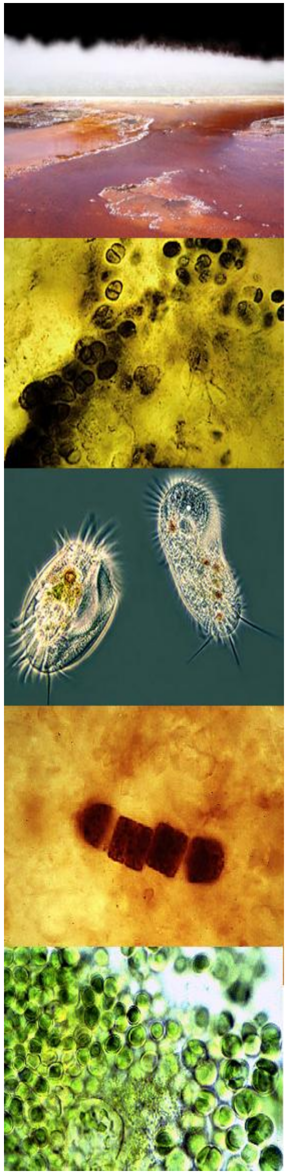
ExoMars Rover Program Level Objectives

Technology Objectives:

- Surface mobility with a Rover
- Access to the subsurface to acquire samples;
- Sample preparation and distribution for analyses by scientific instruments.

Scientific Objectives:

- To search for signs of past and present life on Mars;
- To investigate the water/geochemical environment as a function of depth in the shallow subsurface;
- To investigate Martian atmosphere trace gases and their sources.

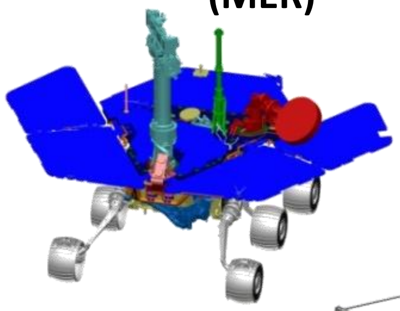


ExoMars Rover Top Level Requirements

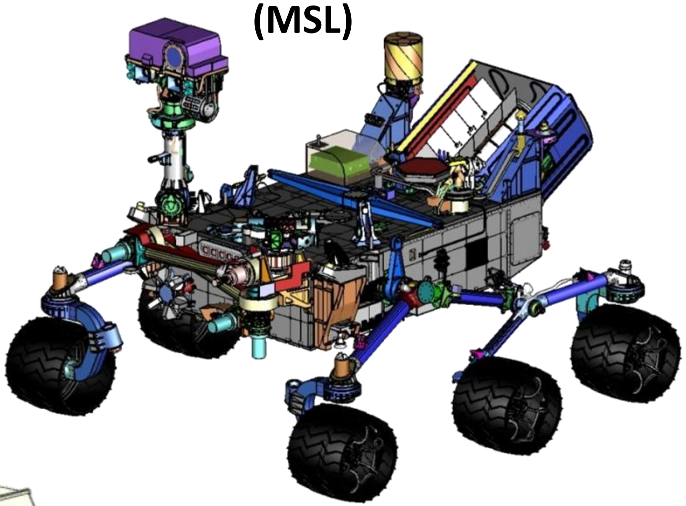
- Be launched to Mars in 2018 opportunity and landed at Ls 324.
- Be compatible with the “to be agreed” configurations constraints of the NASA “Skycrane”, and the associated deployment and egress constraints of its landed platform.
- Be capable of operating at altitudes [-1.0 1.0] km relative to the MOLA aroid.
- Be capable of operating at sites between [35°N and 5°S] latitude.
- Be capable of operating at sites with 7% rock abundance and [99.7%] areal density of up to [21.5°] slopes at 5m length scale.
- Be capable of operating for a total traverse path length of at least [3] km.
- Accommodating [7 (or 9)] scientific instruments: [3 (or 4)] survey instruments and [4 (or 5)] analytical laboratory instruments.
- Be capable of conducting Mars sample location selection, sub-surface sample collection down to 2m depth, and sample analysis operations at [6] different locations for at least [180] sols.
- Be capable of processing at least [26] core samples.

NASA Rover Family Comparison

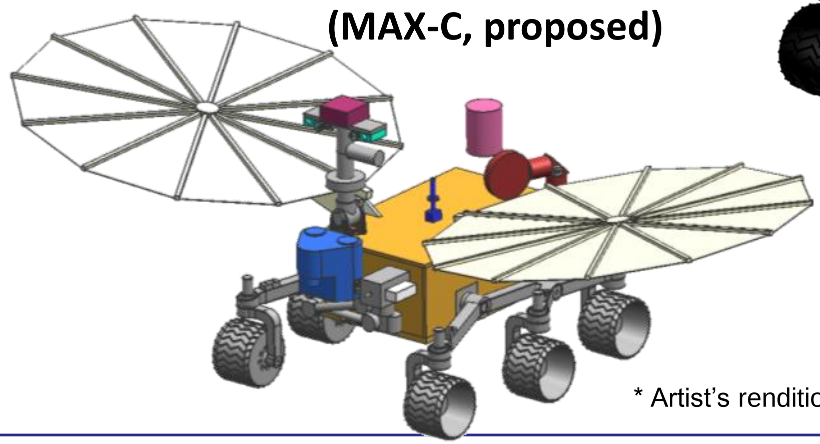
Mars Exploration Rovers (MER)



Mars Science Laboratory (MSL)



Mars Astrobiology Explorer (MAX-C, proposed)



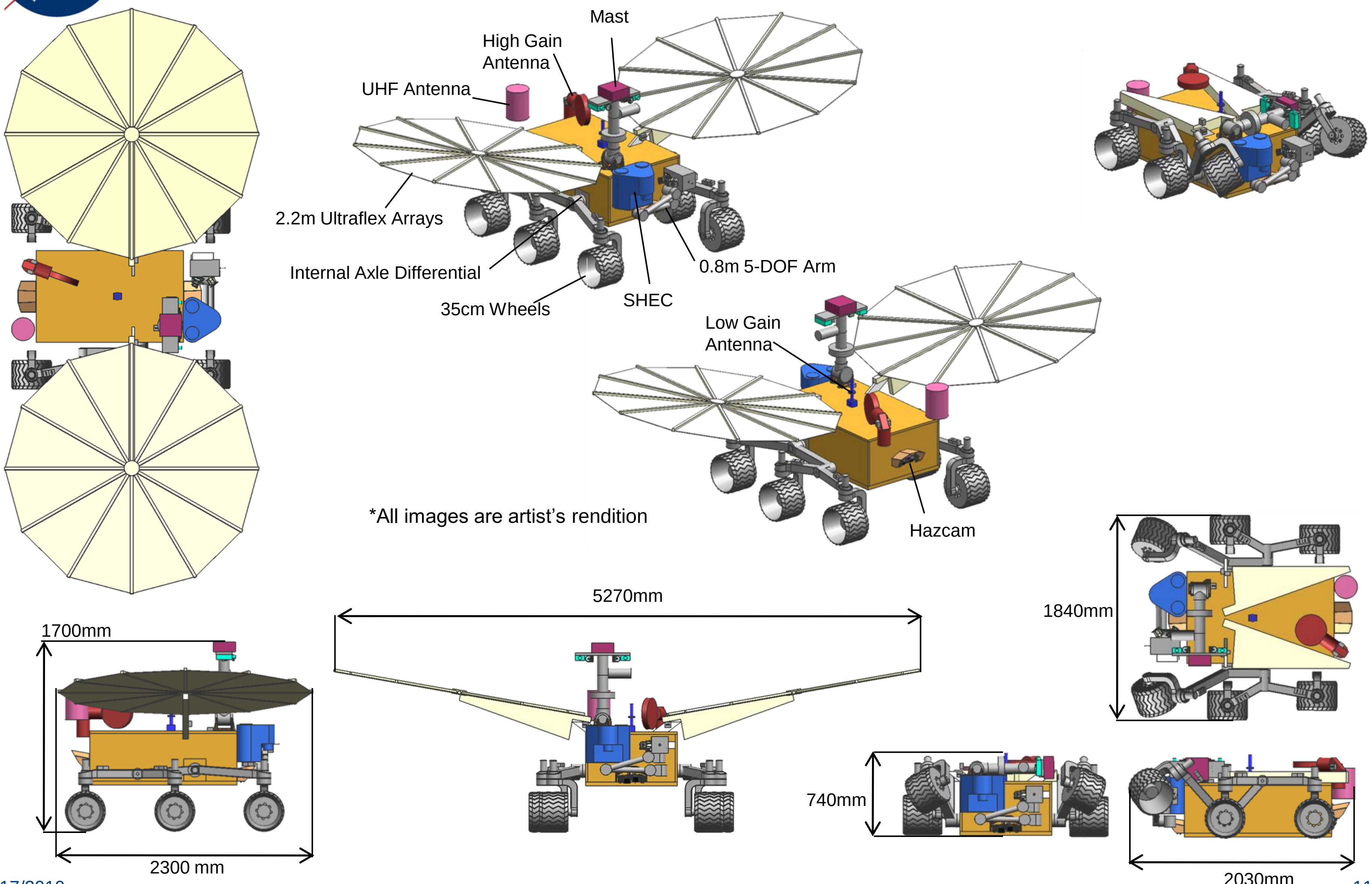
* Artist's rendition

Mars Pathfinder (MPF-Sojourner)

Instruments + Science Support Equipment Mass			
MPF (Sojourner)	MER	MAX-C (proposed)	MSL
~1 kg total	5+16 kg	~15+47 kg	82+155 kg
Rover Total = 11 kg	Rover Total = 173 kg	Rover Total = ~340 kg**	Rover Total = ~965 kg

** CBE mass is ~238 kg. PBE is ~340 kg with full 43% contingency on CBE.
CBE = Current Best Estimate PBE = Predicted Best Estimate (with contingency)

Proposed MAX-C Rover Configuration/ Size



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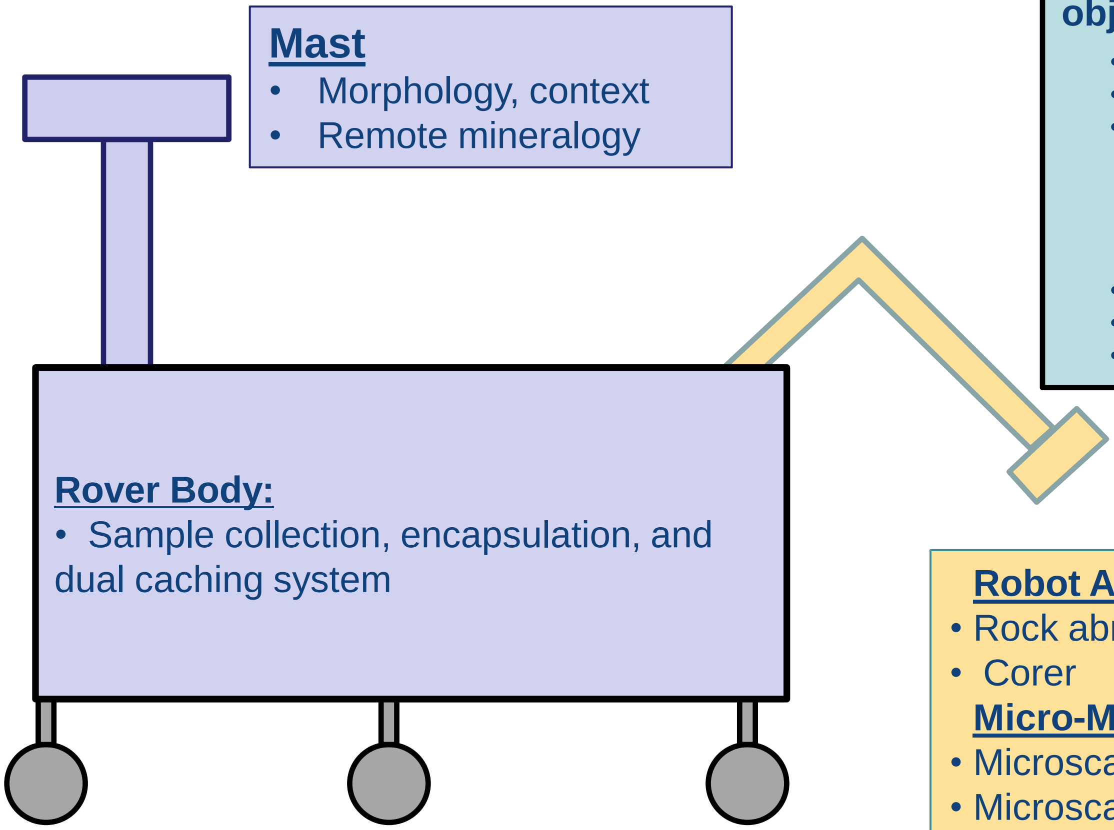
MAX-C Strawman Payload Concept

Select targets and establish context



Sample Caching

Functional requirements needed to achieve the proposed MAX-C scientific objectives:

- Access to outcrops (mobility)
- Remote target selection capability
- Rock/soil interrogation
  - Chemistry
  - Mineralogy
  - Organics
  - Texture
- Documentation of sample context
- Sample via coring
- Encapsulation of cores

Rock and Soil Interrogation

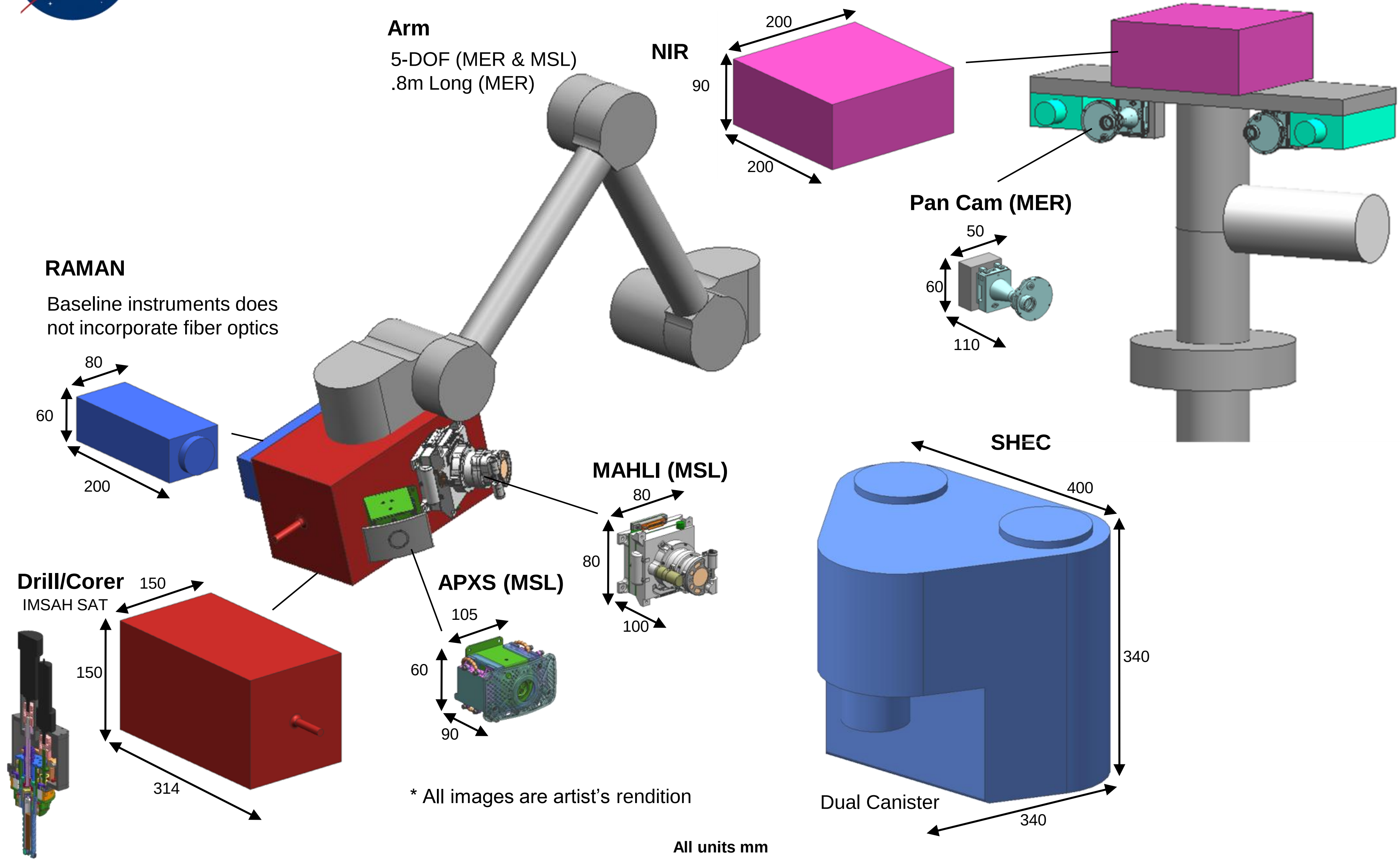
Robot Arm:
- Rock abrasion tool (corer bit or possible RAT)
- Corer

Micro-Mapping Package:
- Microscale visual imaging
- Microscale mineralogy imaging
- Microscale organic imaging

Coarse Analysis:
- Bulk elemental chemistry

For planning and discussion purposes only.

MAX-C Strawman Payload Configuration/ Size



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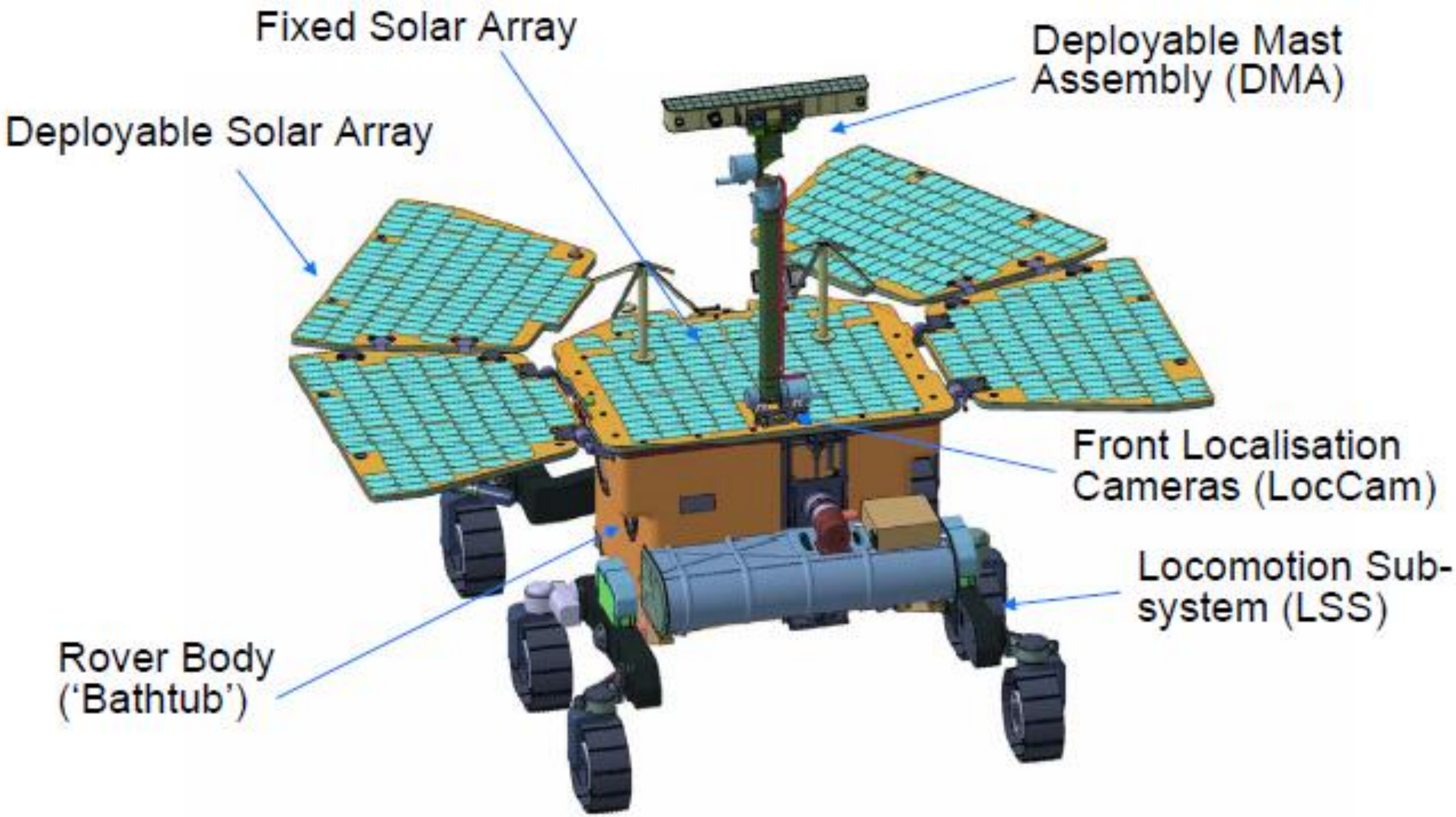
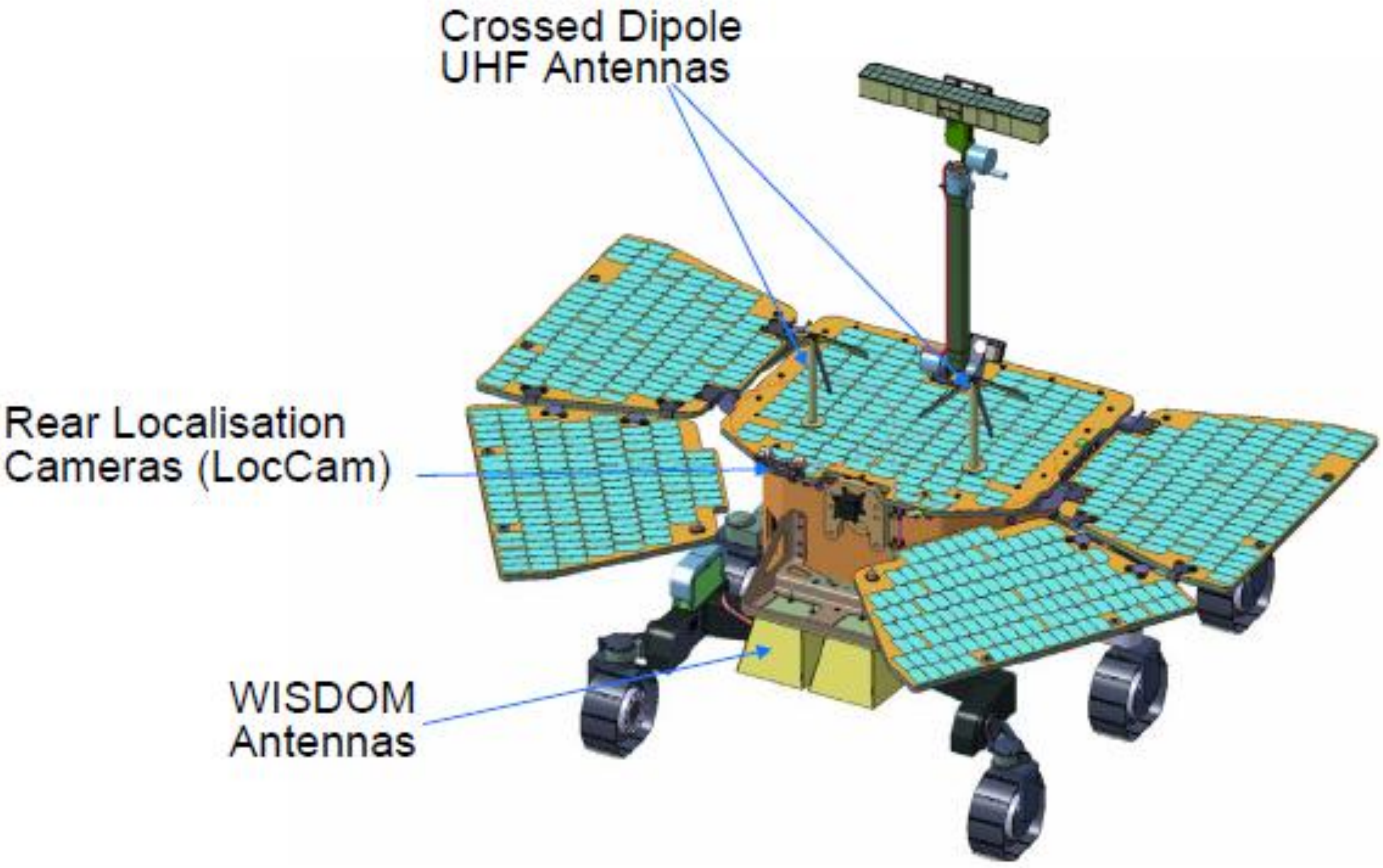
All units mm

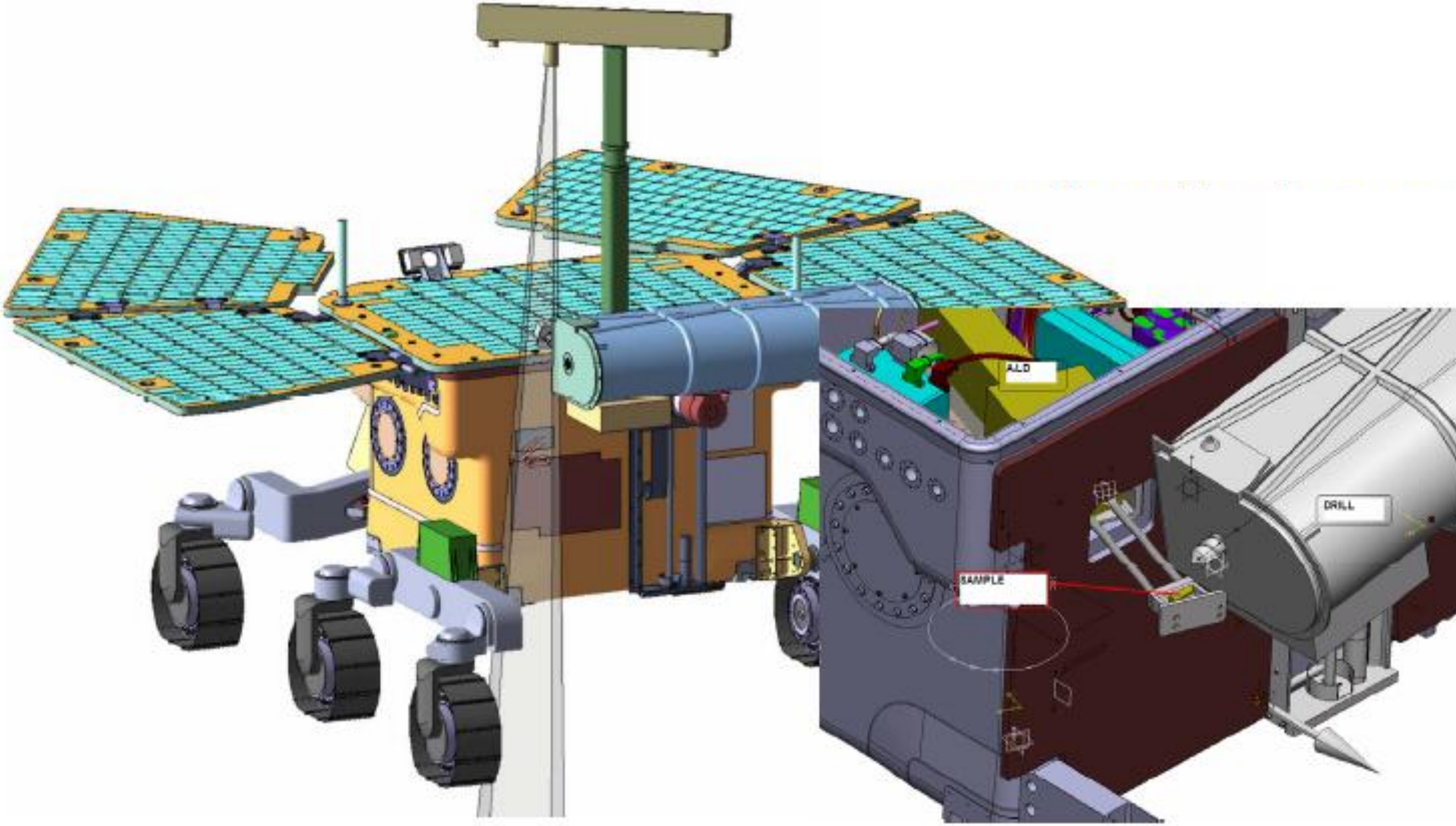
Deployed configuration (1/2)



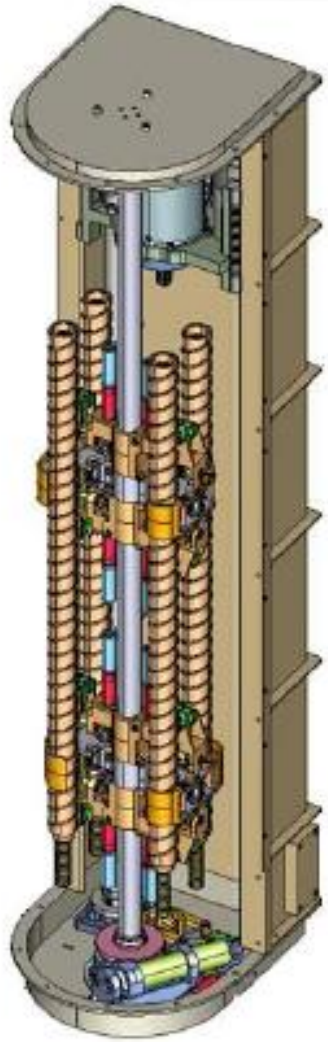
Deployed configuration (2/2)



HRC can observe sample as delivered by the Drill



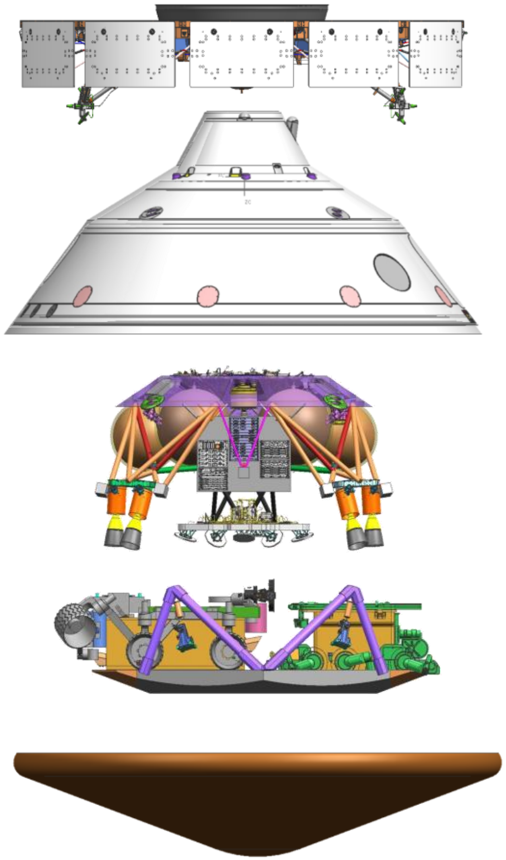
Drill



Drill Tool with sample acquisition mechanism

Proposed MAX-C Overview

Baselined Major Mission/Spacecraft Attributes	
Science Capability	Remote and Contact Science *(Color stereo imaging, macro/micro-scale mineralogy/elemental, micro-scale organic detection/characterization, micro-scale imaging)* Coring and Caching Rock Samples for Potential Future Return
Mass Allocation (Launch/Entry/Landed)	4440/ 3700/ 970 kg **
Launch Vehicle (Baseline)	Atlas V 531
Power/Energy per Sol	Cruise: 1250 W Solar Surface: ~1600 WHrs/sol Solar
Cruise ACS	Stable Spinner (MSL Design)
Landing Site (Ellipse/ Altitude/ Latitude)	11 km radius / -1.0 km / +25 to -15 degrees
Entry Vehicle Diam. / Parachute Diam.	4.7 m / 21.5 m
Landing System	Skycrane throttled monoprop with landing pallet
Rover Mast Height / Wheelbase	~1.7 m / ~1.6 m
Ground Clearance/Wheel Diam.	~0.42 m / ~0.35 m
Data Return per Sol (2-week average)	~250 Mbits UHF (w/TGMI); MER/MSL-class Xband DTE
Data Storage	32 Gbits
Science Payload Mass	~15 kg instruments ~62kg including coring/caching/mast/arm
Motor Architecture	Brushless – hybrid distributed electronics
Traverse Capability (Design Distance)	20 km
Flight Software	MSL-based
Surface WEB Thermal Range/ Design	-40C to +50C / CO2 gap insulation, RHUs, supplemental htrs
Surface Design Lifetime	500 Sols



* All images are artist's rendition

*** Landed mass includes NTE ExoMars Rover allocation of 300 kg, and allocation for the proposed MAX-C Rover plus Landing Platform of 670 kg – baseline predicted best estimate (PBE) with 43% contingency.*

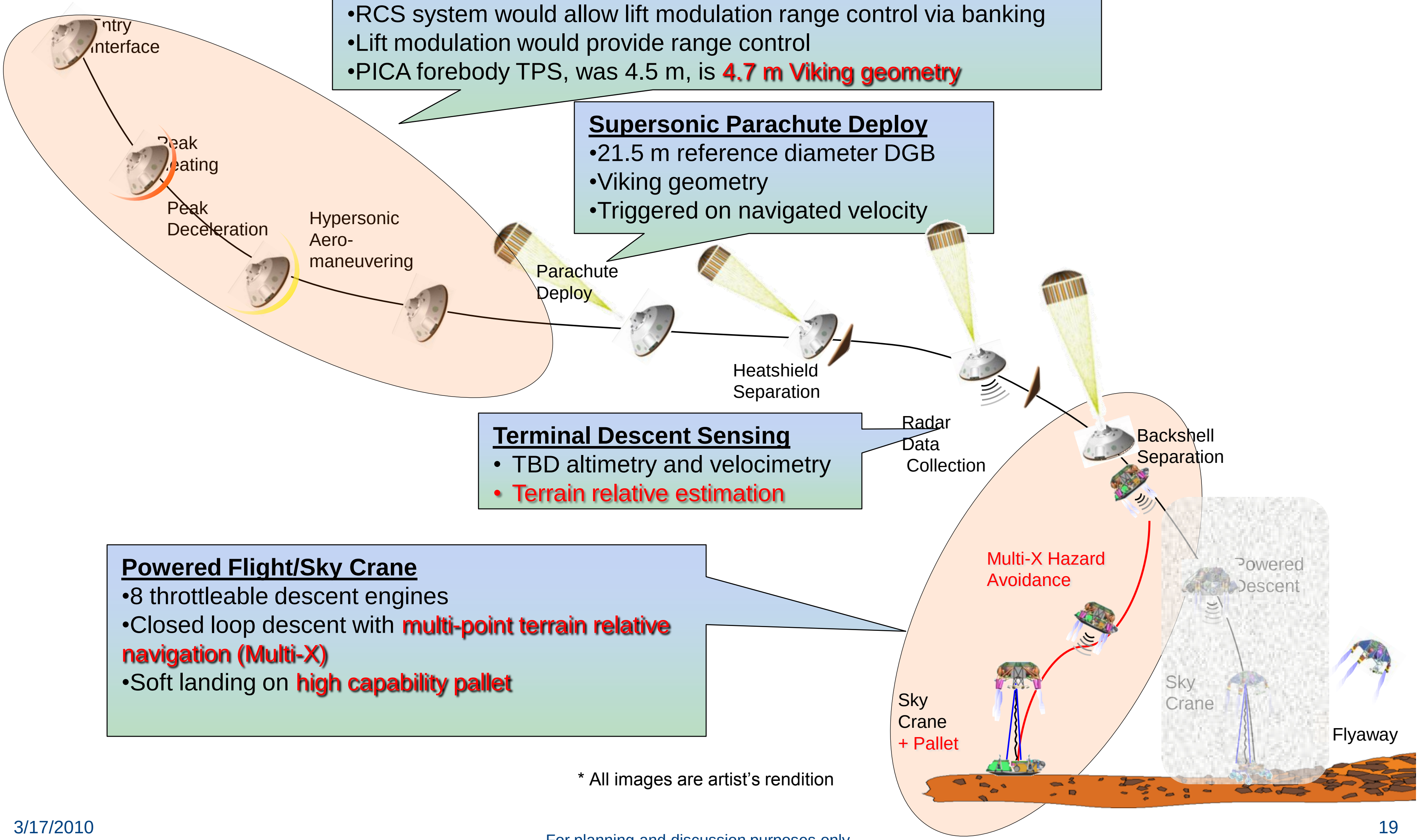
Proposed MAX-C/MSL EDL Architecture

Guided Entry
- CG offset to provide angle of attack/lift (0.24 L/D)
- RCS system would allow lift modulation range control via banking
- Lift modulation would provide range control
- PICA forebody TPS, was 4.5 m, is 4.7 m Viking geometry

Supersonic Parachute Deploy
- 21.5 m reference diameter DGB
- Viking geometry
- Triggered on navigated velocity

Terminal Descent Sensing
- TBD altimetry and velocimetry
- Terrain relative estimation

Powered Flight/Sky Crane
- 8 throttleable descent engines
- Closed loop descent with multi-point terrain relative navigation (Multi-X)
- Soft landing on high capability pallet



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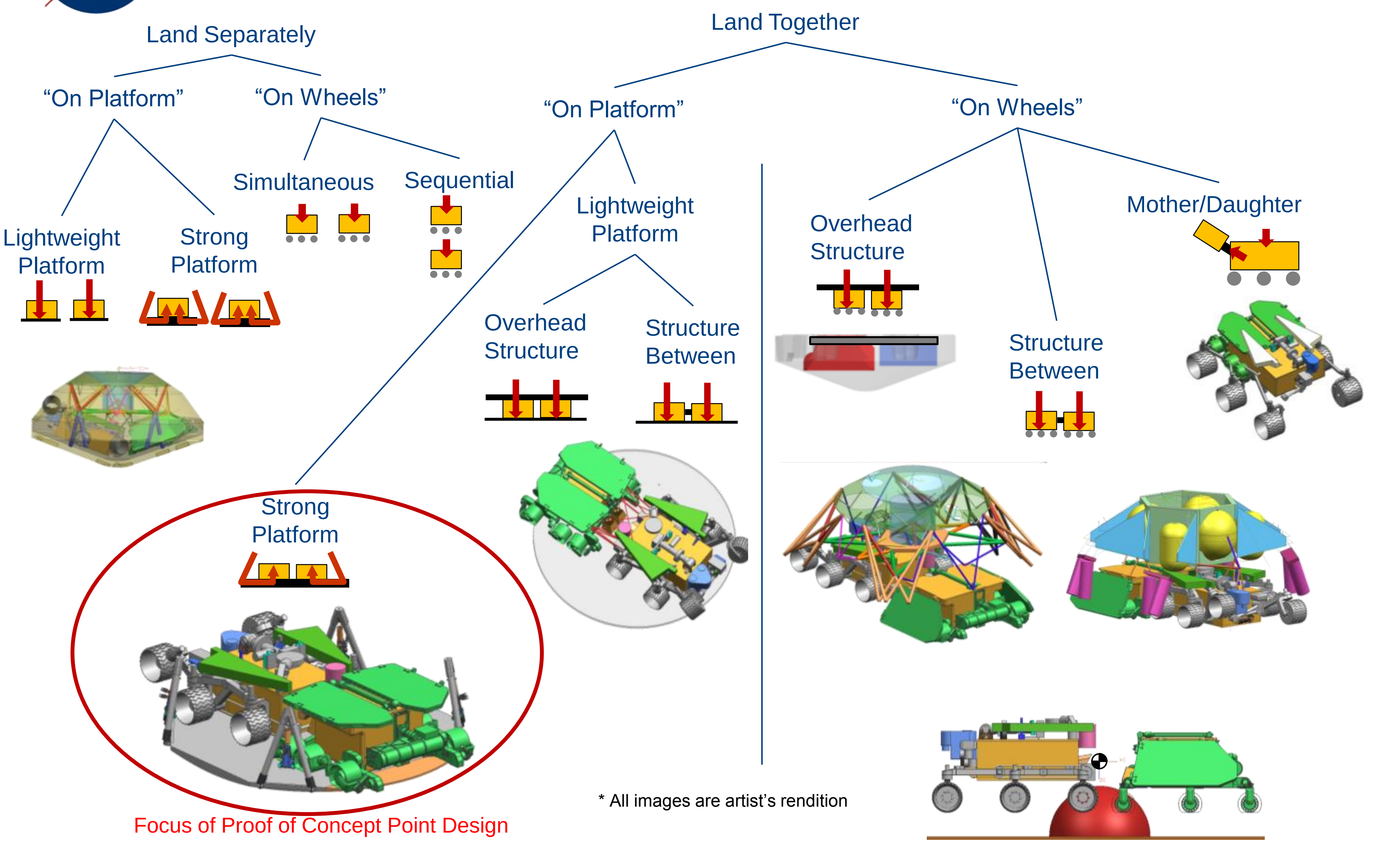
How To Skycrane a Pair of Rovers



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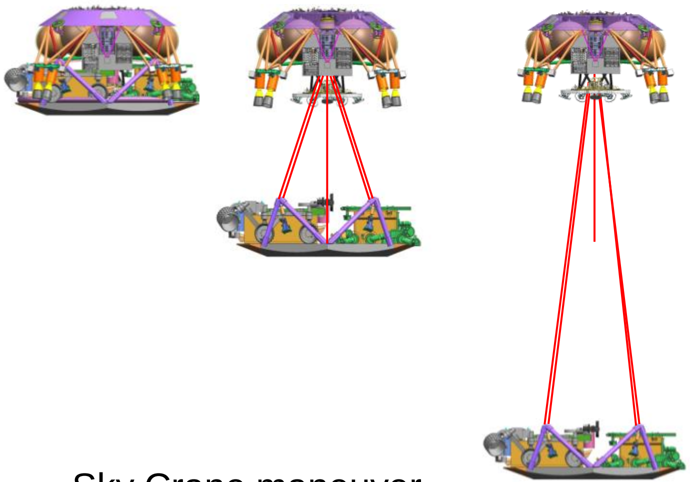
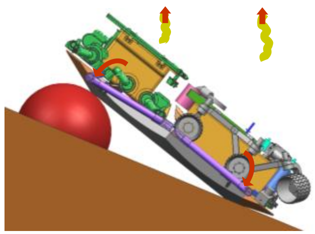
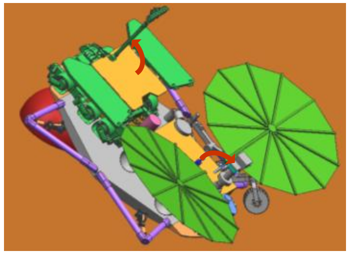
Landing Through Egress Overview



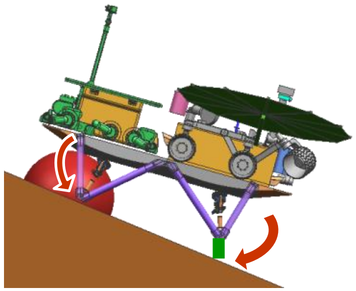
Sky Crane maneuver

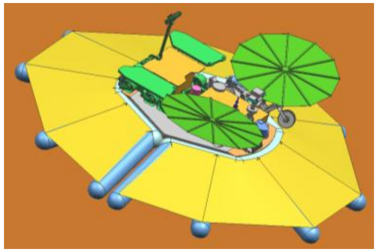
Touchdown Through Initial Deployments



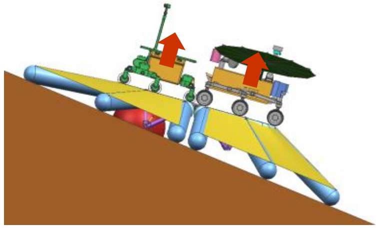


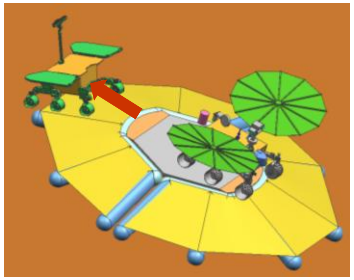
Platform Leveling Through Ramp Deployment





Stand Up Through Egress





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Summary

Yes, we could deliver the proposed MAX-C and ExoMars rovers together to the surface of Mars.

- We have fleshed out a design on one particularly promising branch of the architectural option space to answer a question of feasibility.
- The resulting strawman system design was reached by exploring the aspects of the design fundamental to feasibility and with the largest influence on technical resources (e.g. mass, volume, etc.).
- We will now give other branches and sub-branches additional consideration, and then further trade and optimize to simplify the system and balance risk.
- In concert, we will explore implementation options and their influence on the technical design.