MSR

Red Dragon

Mars Sample Return Using Commercial Capabilities:

Mission Architecture Overview

2014 IEEE Aerospace Conference
2.0612 Wed. 3/5/2014 Ver. 3.2A

Andrew A. Gonzales, Carol R. Stoker,
Lawrence G. Lemke, *and* **Jeffrey V. Bowles**
NASA, Ames Research Center

Loc C Huynh
Science and Technology Corp.

Nicholas T. Faber
Stinger Ghaffarian Technologies

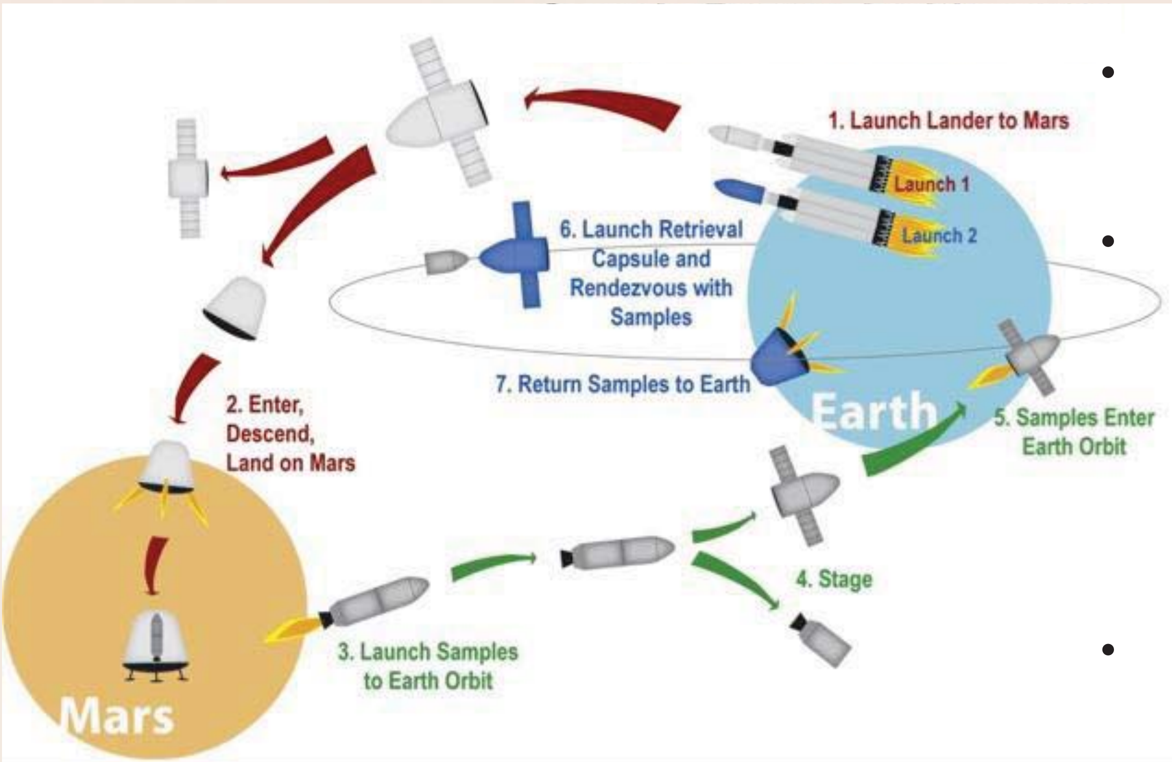
Margaret S. Race
SETI Institute

Introduction

- Mars Sample Return (MSR) is the highest priority science mission for the next decade as recommended by the recent Decadal Survey of Planetary Science.
- This presentation provides an overview of a feasibility study for a MSR mission in which emerging commercial capabilities are used alongside other sources of mission elements.
- Goal is to reduce the number of mission systems and launches required to return the samples, with the goal of reducing mission cost.
- Major elements required for the MSR mission are described.
- We report the feasibility of a complete and closed MSR mission design

Mission Architecture Description

MSR
Red Dragon



- Falcon Heavy places Red Dragon capsule on Trans Mars Injection trajectory.

- Red Dragon is modified to carry required hardware
  - Mars Ascent Vehicle (MAV)
  - Earth Return Vehicle (ERV)
  - Mission support hardware
  - Arm to transfer a sample from a previous rover mission (i.e. 2020 rover) to the ERV

- Red Dragon performs lifting trajectory EDL with Supersonic Retro Propulsion *EDL paper at this 2014 IEEE Aerospace conference*

- Mars Ascent Vehicle (MAV) launches Earth Return Vehicle (ERV) with sample from the surface to brief Mars phasing orbit.

- Mission can start in preferred 2022 opportunity or as late as 2026

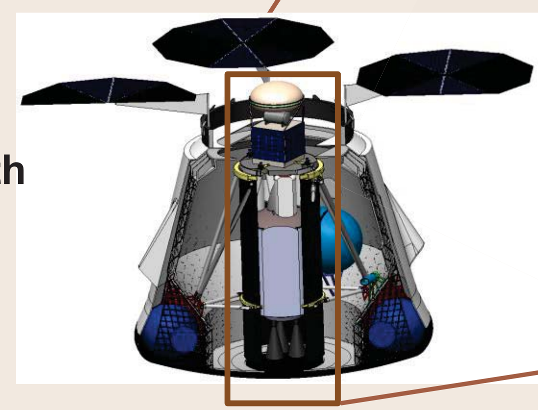
Red Dragon MSR System Elements

Emerging Commercial Capability

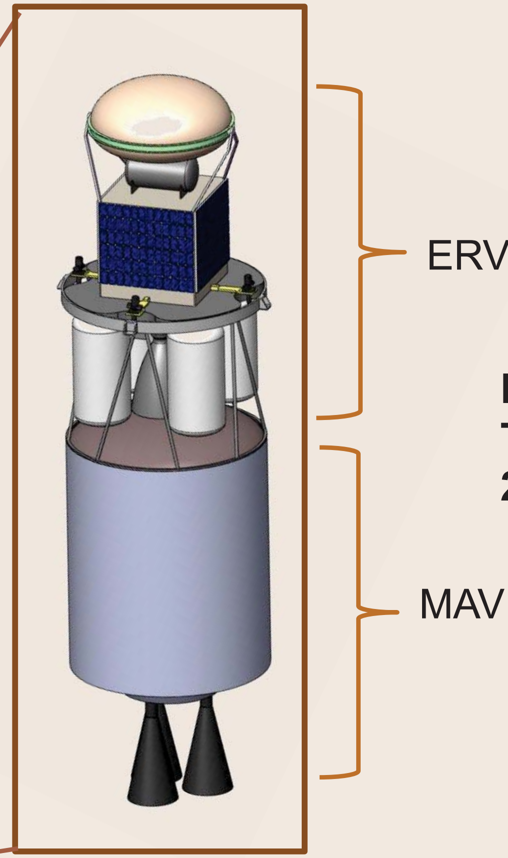
Falcon Heavy with
Red Dragon
to Mars 2022

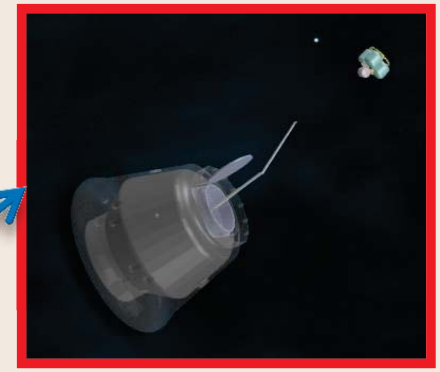
*Launch abort motors
already in development*

Red Dragon, Landing



Cutaway View of Red Dragon*
Modifications

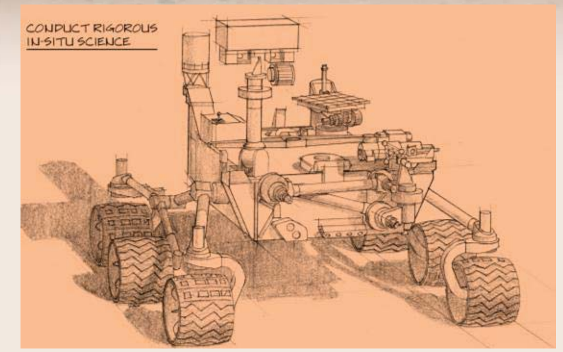




Enter sample into Lunar-Trailing Orbit (LTO) with 2025 mission to retrieve

Falcon Heavy with Dragon to
Lunar Trailing Orbit

Red Dragon MSR System Elements



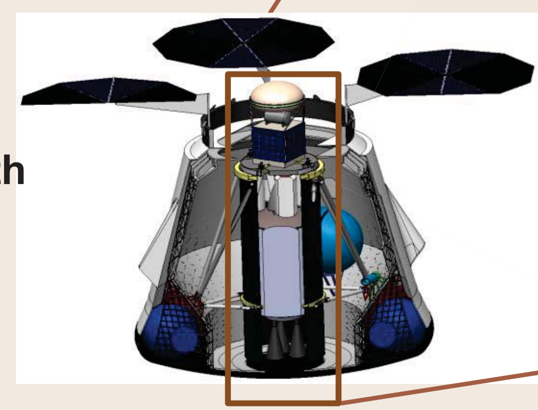
Mars 2020 rover

Emerging Commercial Capability

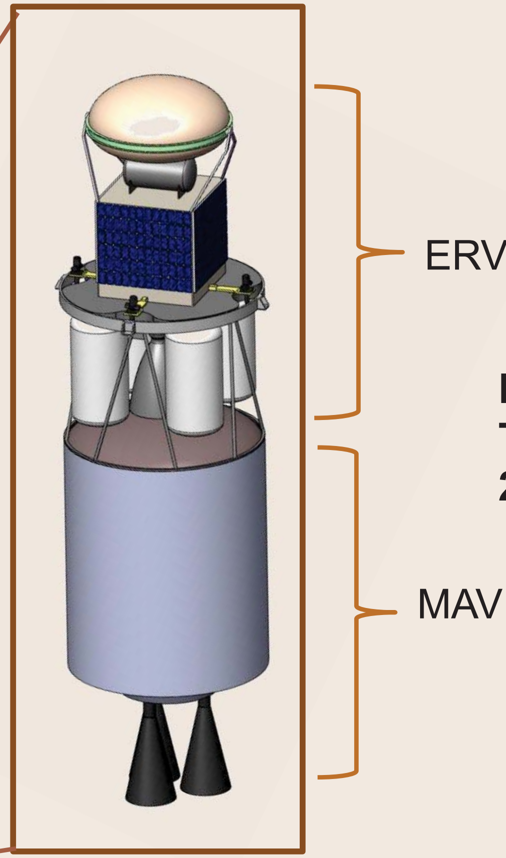
Launch abort motors already in development

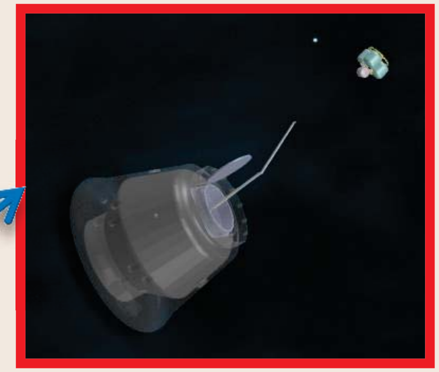
Red Dragon, Landing

Falcon Heavy with Red Dragon to Mars 2022



Cutaway View of Red Dragon* Modifications





Enter sample into Lunar-Trailing Orbit (LTO) with 2025 mission to retrieve

Falcon Heavy with Dragon to Lunar Trailing Orbit

Study Approach for Red Dragon MSR

How much mass and volume is required for MAV, ERV and support systems?

- Conducted integrated parametric optimization studies for MAV & ERV using linked Aerospace engineering tools – Mass Estimating Relationships
- Determined sensitivity of design to: propellant choice, rocket motor design, staging ΔV, aerodynamics, etc.
- Chose baseline designs for MAV & ERV
- Recognized ERV a crucial element that balances the architecture, so performed supplemental bottom-up design of ERV to validate parametric approach

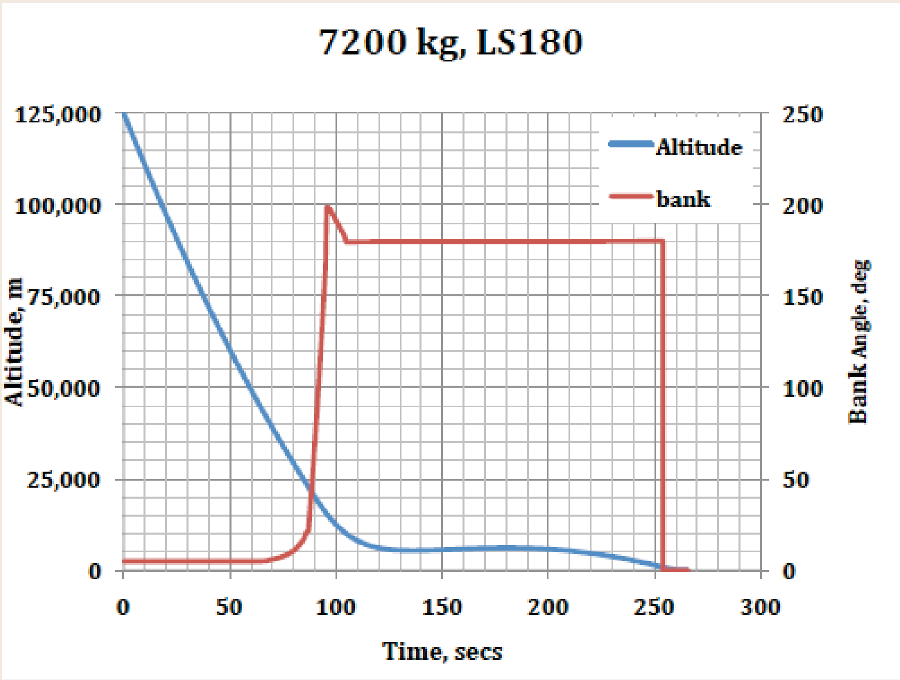
How much mass and volume can Red Dragon deliver to Mars?

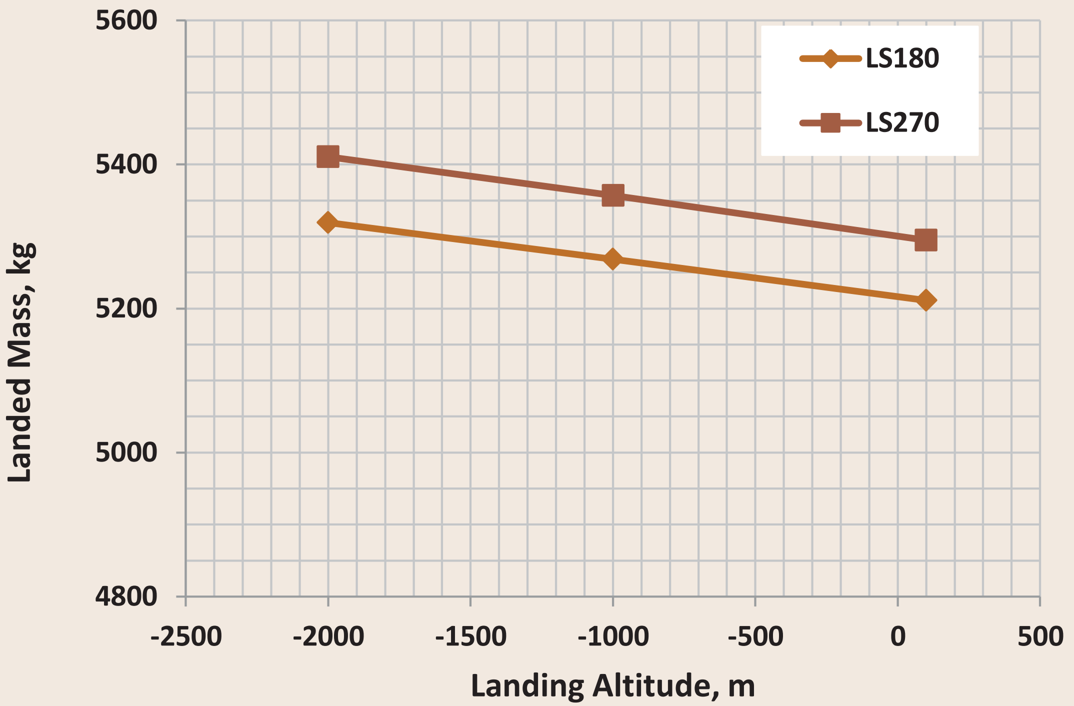
- Constructed aerodynamic model of Dragon
- Obtained data from MARSGRAM atmospheric model
- Included model of retro-propulsion system
- Computed EDL trajectories from entry interface down to surface
- Used computational tools, including POST
- Determined mass limit for successful EDL

Will This……………….Fit Into………………This?

EDL

Red Dragon performs lifting trajectory
EDL with Supersonic Retro Propulsion
EDL paper at this 2014 IEEE Aerospace conference

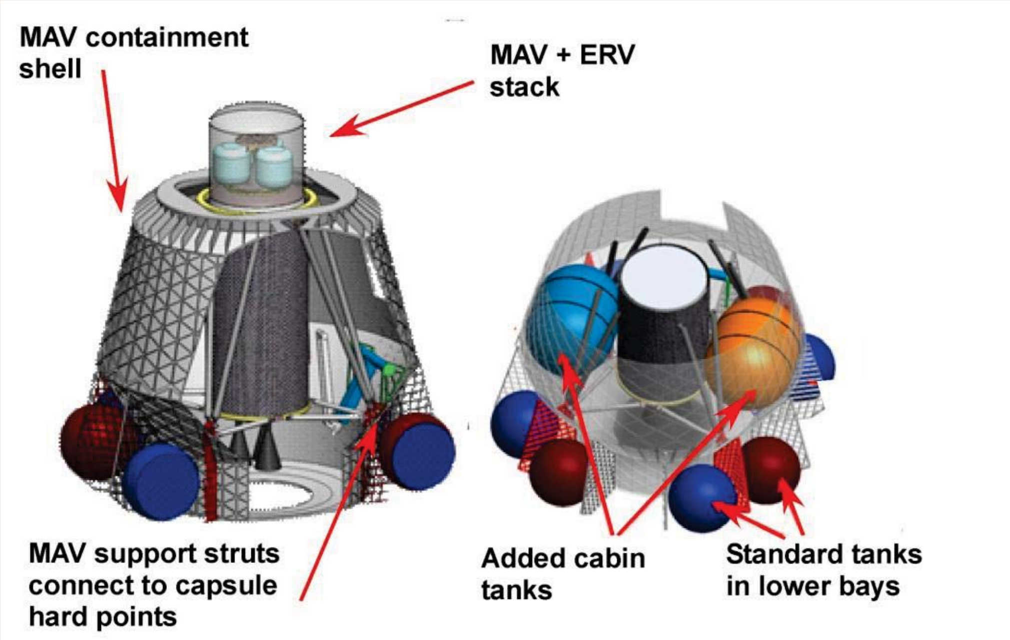




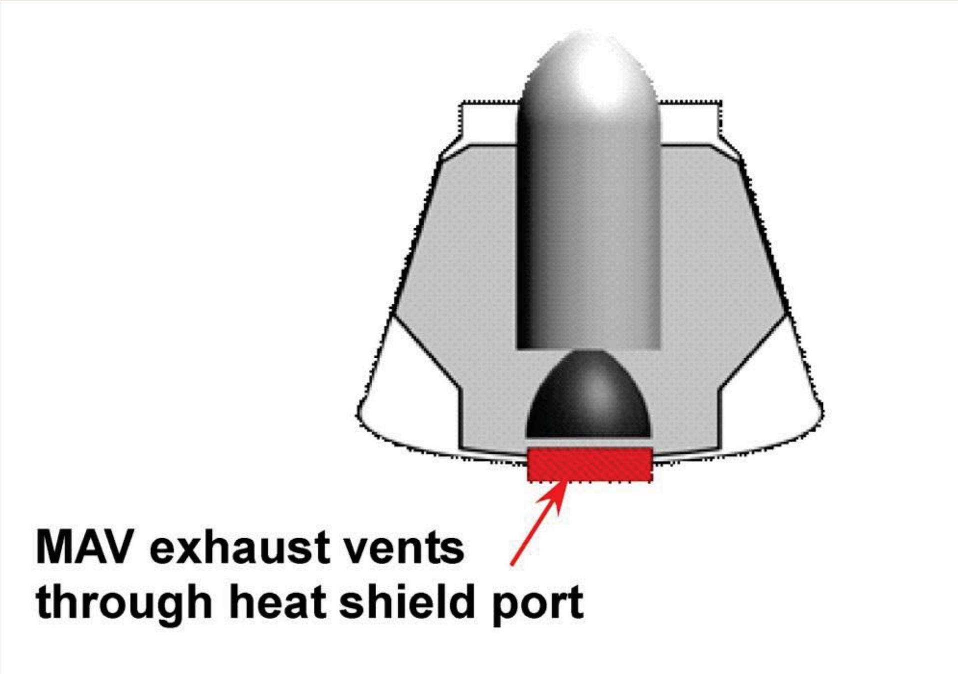
Arrivals occur near atmospheric minima

Red Dragon Internals

MSR Red Dragon



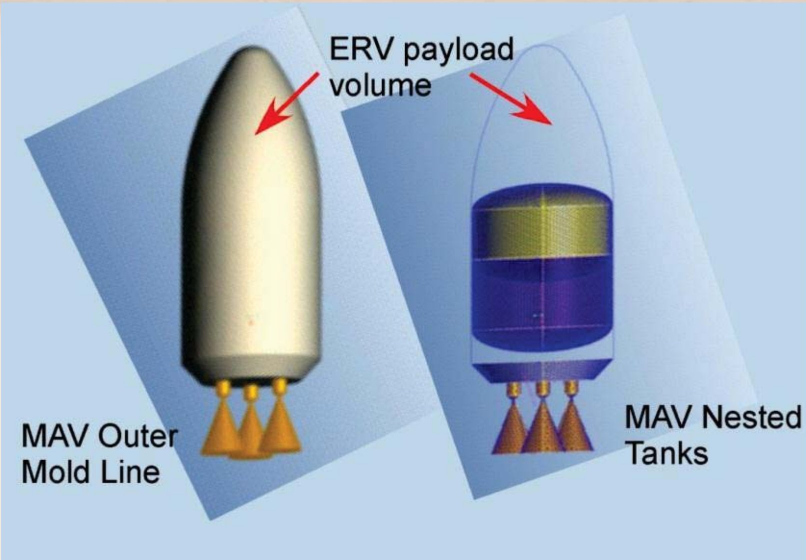
Internal supports and EDL propellant tanks



Exhaust Venting

MSR Red Dragon

Mars Ascent Vehicle



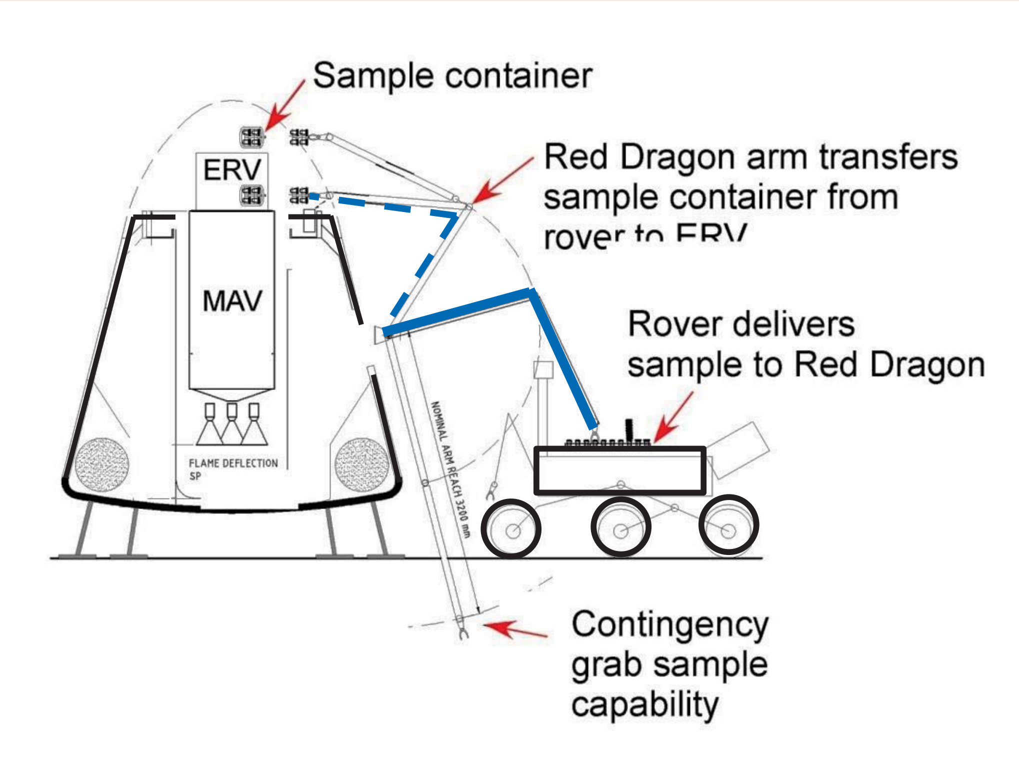
Item	Value
MAV + ERV length	2.80 m
Maximum Diameter	1.02 m
GLOM	1,300 kg

Over 100 combinations varying

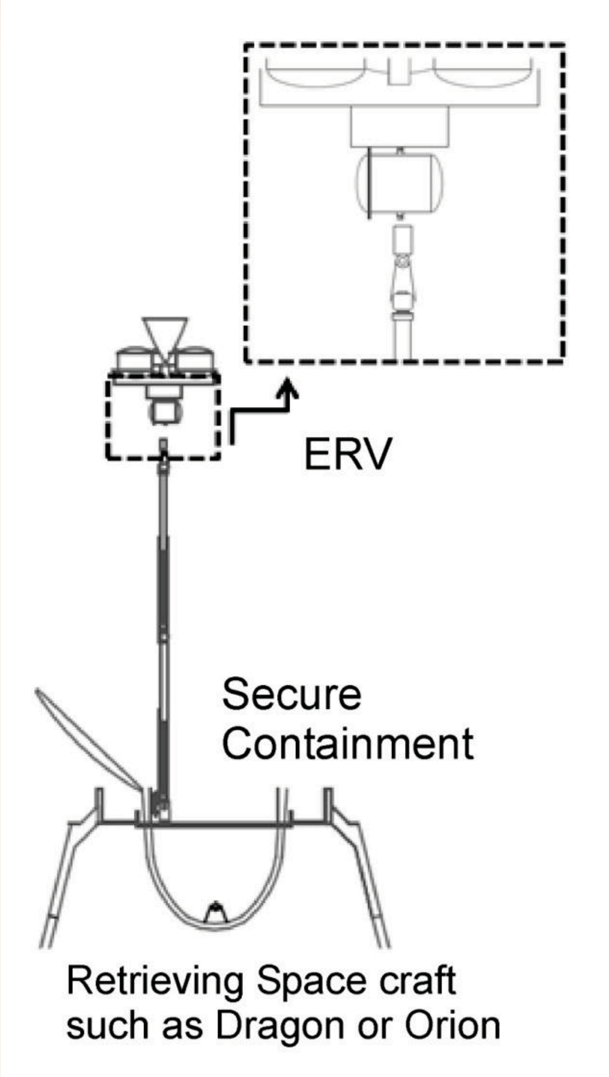
- **ΔV split with ERV**
- **Engine performance and number**
- **Propellant type**
  - ✓ **Storable**
  - ✓ **Cryrogenic (ISRU)**

- DV budget distribution between MAV and ERV optimized
- Best design and analysis practices for conceptual design
- Mass Estimating Relations used to compute mass and volume, including growth allowance
  - ✓ Performance.
  - ✓ Structures
  - ✓ power system
  - ✓ propulsion system
  - ✓ nose fairing
  - ✓ thermal insulation
  - ✓ actuation devices
  - ✓ guidance
  - ✓ communication.
- MAV and ERV stack iterated to fit into Red Dragon volume and landing capability .

Sample Transfer

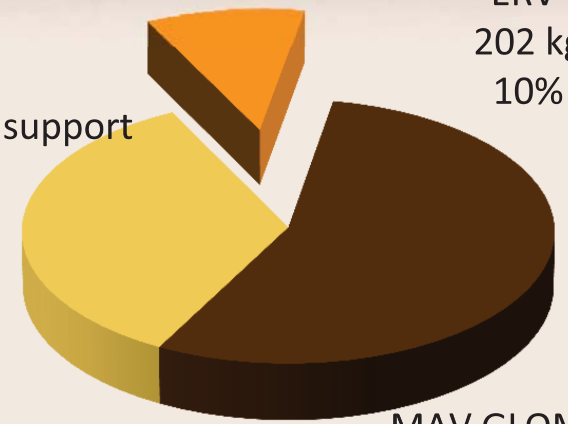


Rover to ERV while in Red Dragon

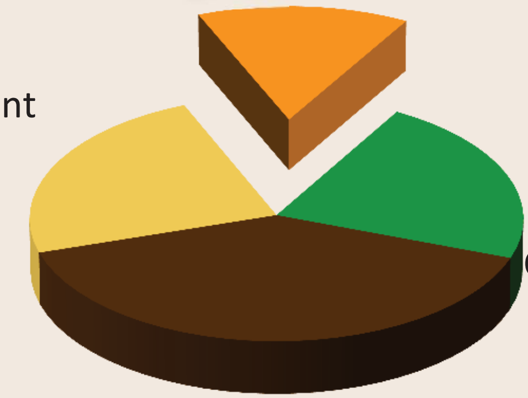


ERV to retrieval vehicle – i.e. an Earth orbiting Dragon

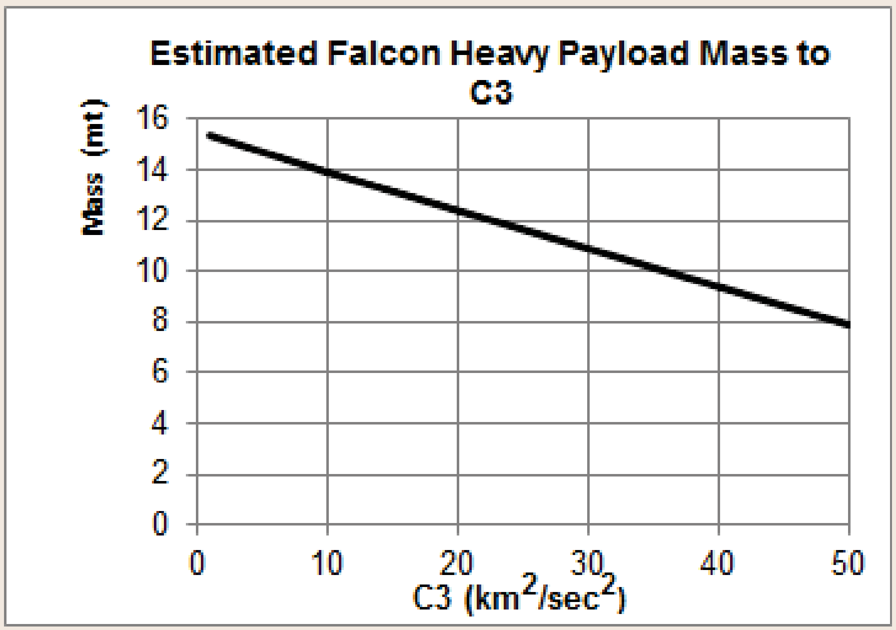
Mass Balance



Landed Payload mass breakdown



MSR High Level MEL Rollup



Tito, D. A., et al, "Feasibility Analysis for a Manned Mars Free-Return Mission in 2018," 2013 IEEE Big Sky Aerospace Conference, March 2013.

Planetary Protection

MSR
Red Dragon

No.	PLANETARY PROTECTION IMPACT ITEMS
1	The exterior surfaces of Red Dragon will be exposed to the terrestrial environment during processing and launch. These surfaces will also be exposed the space environment while in transit to Mars.
2	The interior surfaces of Red Dragon will need to be sterilized .
3	The sample handling robotic arm grab sample end effector will need to be sterilized.
4	The exterior of the sample container delivered by the 2020 rover will be exposed to Mars material and will need to be contained whether it is retrieved in a LTO or is returned via EDE.
5	The exterior surfaces of the ERV will be exposed to Mars materials. If the ERV is operated in the LTO mode, it will be disposed to a heliocentric orbit. If the ERV is operated in the EDE mode, it will fly-by the Earth after the EEV is targeted to Earth entry, and remain on its hyperbolic orbit. In neither case will the ERV enter the Earth's biosphere or impact the moon.
6	The interior surfaces of the EEV, if the EDE mode is used, will be sealed and contained after the sample container is loaded onboard.
7	The exterior surfaces of the EEV, if the EDE mode is used, will be exposed to Mars. Protecting all of the exterior surfaces, including the sample container loading port, will be a problem area.

Conclusions

- MSR mission in 2022 opportunity that retrieves samples collected by Mars 2020 rover technically feasible with the use of emerging commercial technologies.

- A formal cost estimate is the next step to be undertaken -- a lower overall cost than for earlier approaches seem likely since technical feasibility has been established.

  - ✓ Apportioned cost of Mars 2020 Mars rover, including short extension should be included in any estimate – any MSR will have to depend on the 2020 rover.

  - ✓ Alternatives for sample retrieval at Earth, including direct entry, should be explored and traded.

Future Work

No.		TASK SCOPE
1	Mission Cost Estimate and Explore Partnership Opportunities	Determine a realistic engineering cost estimate, and determine partnership opportunities
2	CFD Study of Supersonic Retro-propulsion	Mission specific application of Supersonic Retro Propulsion
3	Earth Return Vehicle design studies – technical elements equivalent to pre ϕ A study.	Define and Document a study that defines a full set of mission and spacecraft requirements and provides a preliminary design using COTS components with appropriate margins and growth allowances.
4	Detailed study of a lighter weight EEV to allow reconsideration of EDE.	Application of current Thermal Protection System technology and addressing containment and high reliability entry and transfer requirements imposed by Planetary Protection Policy[7]. Trade study of EEV development versus the cost of a LTO retrieval mission.
5	Detailed study of Mars Ascent Vehicle (MAV).	Application of current technology from DoD programs.

Author Contributions, Acknowledgements & Disclaimer

Author Contributions

Andrew A. Gonzales, Systems Engineering
Lawrence G. Lemke, Engineering and ERV design
Carol R. Stoker, Study Principal Investigator
Jeffrey V. Bowles, MAV parametric design
Loc C. Huynh, Red Dragon entry and MAV ascent
Nicolas T. Faber, sample transfer in Earth orbit and Planetary Protection
Margaret S. Race, Planetary Protection

Acknowledgements

The work described in this paper was performed with funding support from the Ames Center Investment Fund. The contributions of the study team including the following individuals are gratefully acknowledged:
Steven Hu, Project Management
Joseph A. Garcia, ERV parametric design
Cyrus J. Foster, Trajectories
David Willson, sample transfer on Mars and mechanical engineering
Michael Soulage, mechanical engineering
Charles J. Hatsell, Red Dragon internal systems
Eddie A. Uribe, Red Dragon internal systems
Bernardus P. Helvensteijn, ISRU and cryogenics
Jeffrey R. Feller, ISRU and cryogenics
Ali Kashani, ISRU and cryogenics
Sasha V. Weston, trade studies and engineering research
John Love, propulsion
We also appreciate management support from Dr. Simon (Pete) Worden, Dr. Michael D. Bicay, Dr. George L. Sarver, and Chad R. Frost.

Disclaimer

The work described in this paper was performed internally by NASA's Ames Research Center using information in the public domain and without the assistance of any commercial organization. There is no endorsements of any particular commercial organization by NASA. There is also no endorsement of this work by any particular commercial organization.

Backup

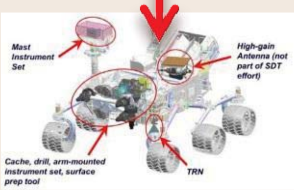
Red Dragon MSR System Elements

Launch 2

Launch 1

Cruise Stage

SkyCrane

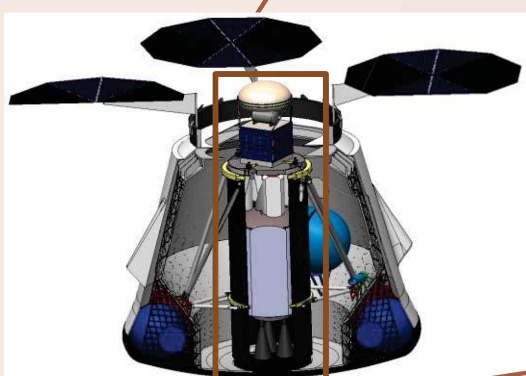


Caching Rover

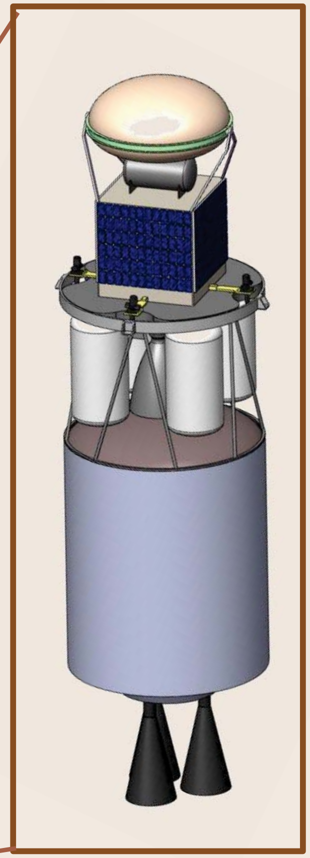
Sample Collection on 2020 Mission remains the same

Sample Return Architecture

Red Dragon, Landing



Cutaway View of Red Dragon* Modifications



ERV

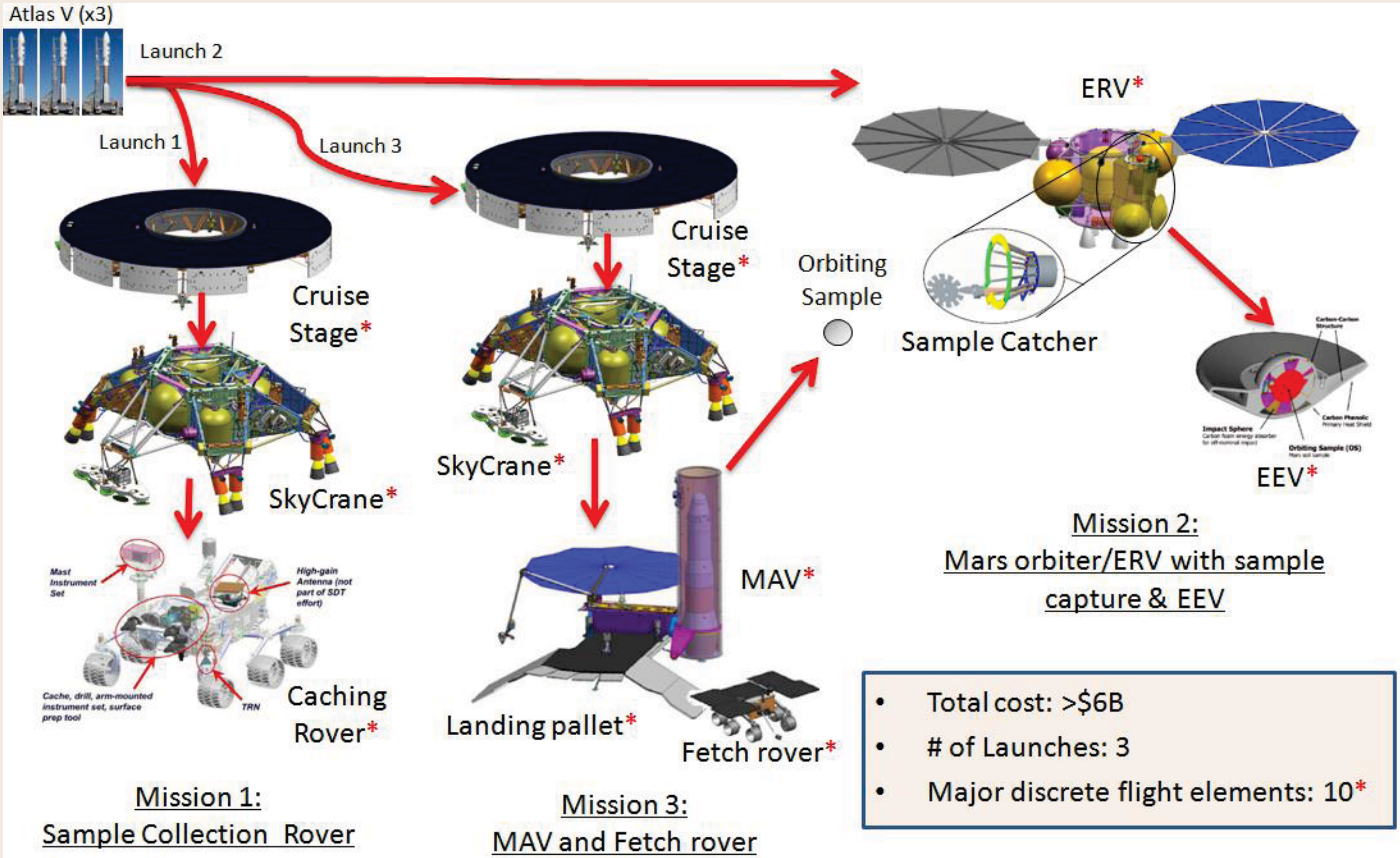
MAV

Enter sample into Lunar-Trailing Orbit (LTO) with subsequent mission to retrieve (Requires Launch 3)

- # of Launches: 2(if EDE) or 3
- Major discrete flight elements: 7

Decadal Survey Taxonomy

MSR
Red Dragon



Key Answers Provided by Ames MSR Architecture study

MSR
Red Dragon

Ames Research Center

- ✓ Is there a simpler, less costly approach to performing the Mars Sample Return (MSR) mission ?
  By using fewer, more capable elements, the parts count, as one indicator of cost, can be reduced. There are development costs but the underlying technology based is strong.

- ✓ Can emerging commercial capabilities be applied to this goal ?
  The SpaceX Dragon capsule is an adaptable platform with Mars mission enabling features either already either built-in or planned

- ✓ Can the proposed architecture be closed ?
  The mass breakdown for all of the required elements has been accounted for. The elements fit together well and landing them is within the landing capability of Red Dragon

- ✓ Are there opportunities to provide value to multiple NASA enterprises
  SMD can move forward with a good, lower cost, option for MSR. HEOMD will get development of key EDL techniques that will be required for human exploration missions/

- ✓ Can the architecture be integrated with other future Mars missions.
  The Ames architecture can land mission anywhere that the 2020 Mars rover can land, as described in the recent Science Definition report and can get their as soon as programmatics allow. A key assumption is that the 2020 rover collects samples and delivers them to Red Dragon. Landing Red Dragon in the path of 2020 is an efficient approach.