



# MARVEL - Online

## A MARVEL is a MARVELOUS Rocket

Mars Ascent Return Vehicle Earth Lift Off Universal System *(Marvelous)* 

Heralds a revolution in rocket design

What does a rocket need to look like? How can we make a platform suitable for iterative design? Vertical Steel or Composites? Fuel Abundance Paradigm? Integration In EU? What is on our taboo wish list? What if you design a rocket like a car or an SUV? Fuel is abundant on Mars, how does this impact our mission and vehicle Can we add on extra functions easily? architecture?

Moon and Mars Capable Universal Platform Reusable Rocket Launcher Deep Space Explorer Single Stage to Orbit MARVEL Mars Ascent Vehicle Phobos & Deimos surface Base Compact Flexible Solar Panels SpaceX beater **Rotating Space Station** 50 KW Solar Power @ Mars Fuel Abundance Paradigm Interplanetary Ferry Droptanks European Aerospike plug Inflatable Fuel Tanks Forward Mars Base Habitat Orbital Tug Artificial Gravity Drop tanks are corridors for crew Cheap Man rated Life Support Vertical Orbital Fuel Depot Integration Reusable Heat Shield @ Mars Ion & Chem propulsion Flash Bainite Metal Construction Deep Throttling Engines Ultra Low Launch Stack (18m) Propellant Factory through pit launch Autonomous cargo unloading Truck like operations **Rotating Space Station** Wheeled surface mobility

Moon and Mars Capable Reusable Rocket Launcher Deep Space Explorer Radiation protection with fuel Single Stage to Orbit MARVEL Phobos & Deimos surface Base Mars Ascent Vehicle **Compact Flexible Solar Panels** Triple redundant Thrust 50 KW Solar Power @ Mars Rotating Space Station Fuel Abundance Paradigm Inflatable Fuel TanksForward Mars Base HabitatOrbital TugInflatable Fuel TanksArtificial Gravity European Cheap Man rated Life Support Drop tanks are corridors for crew Vertical Orbital Fuel Depot Integration Reusable Heat Shield @ Mars Ion & Chem propulsion Flash Bainite Metal Construction Deep Throttling Engines Ultra Low Launch Stack (18m) Propellant Factory through pit launch Autonomous cargo unloading Truck like operations **Rotating Space Station** Wheeled surface mobility



## MARVEL

MARVEL replaces up to 13 vehicles



## ... IS MARVELOUS

## MARS ASCENDER

## **RETURN VEHICLE**

## EARTH LIFT OFF

UNIVERSAL SYSTEM

## MARVEL

For more than 5 decades rockets have looked almost identical and had comparable performance. If we want to develop the inner solar system, we have to do better. At Leopard Space Systems we can and will guarantee spot to spot delivery.

MARVEL litterally turns rocketry on its head by putting the engines at the top of the vehicle. By reassembling tested and heritage rocket elements in an innovative configuration and using modern digital engine controls we achieve an unprecedent increase in performance while not having to rely on exotic propulsion schemes.

Designed from the start as a MARS FERRY this rocket starts from a RESOURCE ABUNDANCE PARADIGM as MARVEL produces its own propellant on Mars.

Think of MARVEL as a modern cargo plane. We can deliver cargo and crew around the world, refuel and do it again. Litterally. However. Using a new type off ION Propulsion (> 14,000 ISP), and reusable heat shield technology, we also perform interplanetary surface delivery services, 10 metric tons at a time.



## Performance Payload to EARTH Orbit / 30 metric tons Payload to Mars Surface / 10 mtons Up down Ferry Capability @ Mars / 20 – 50 metric tons Total Vehicle weight @ Earth Lift Off / Up to 500 metric ton Dry Weight / 12 metric tons Propulsion Aerospike Plug + Droptanks Liquid Methane/Liquid Oxygen, 600 Mton Thrust, 380 ISP 18 engines Neumann Propulsion in orbit (> 14,000 ISP) Construction Flash Bainite Steel (1,500 MPA) + Composites Outer Diameter 8,5 m / Droptank Diameter 3,66 m

Reusable Heatshield in Mars Conditions

Triple redundant propulsion & Landing gear

## MARVEL



#### MARVEL is designed to be fully reusable

A host of innovations allow us to beat the competition on price, performance, versatility and reliability. Some examples:

A pressure fed engine stage enables a low complexity vehicle. It can refuel and take off autonomously in a reliable manner.

A Conformal Aerospike means more payload per launch as the configuration uses propellant up to 30% more efficiently.

Powerful methalox engines guarantee a long operational life as the fuel cleanses the thrust chambers.

MARVEL uses a new weldable steel that is stronger, 30% lighter and cheaper than aluminium. It hardly uses labour intensive and expensive composites while obtaining the same weight benefits.

#### Propulsion

Aerospike Plug + Droptanks

Liquid Methane/Liquid Oxygen, 600 Mton Thrust, 380 ISF

18 engine

Neumann Propusision in orbit (> 14,000 ISP



## MARVEL





## Engines on top

Dr. Robert H. Goddard, the American rocket pioneer got it right.

Rocket engines belong on top of the vehicle.

Modern computers, control mechanisms and materials allow us to do what he had in mind.

As a result MARVEL has only one engine stage.

Where all other modern rockets have to throw away expensive rocket engines to reach orbit, MARVEL only ejects propellant drop tanks, but even these can be reused.

#### Construction

Flash Bainite Steel + Composites

Outer Diameter 8,5 m / Droptank Diameter 3,66 m

Reusable Heatshield in Mars Conditions

Triple redundant propulsion & Landing gear



## MARVEL

A Direct result of putting the engines on top is that

MARVEL gives you a lot more internal volume for the same expenditure.

It almost seems like ...

... common sense.



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## MARVEL

"Once we get MARVEL on the SURFACE of MARS, it can start its job of producing propellant and lifting hundreds of tons of fuel and cargo into Mars Orbit."

#### MARVEL is a MARS FERRY.

An ABUNDANCE PARADIGM drove us to develop a lightweight vehicle that produces its own propellant on MARS.

This 19th century technology enables us to deliver a constan 20 metric ton payload everywhere in the Earth-Mars arena.

Cargo Up Performance from the Mars surface is even better. MARVEL can get up to 40 mton of payload into Low Mars Orbit using its internal propellant tanks and benefiting from the lower Martian gravity. Afterwards it still has enough propellant to safely land on Mars and refuel.

"This disruptive capability will open up the inner solar system for human pioneers as it dramatically reduces the propellant mass to be lifted off from Earth. We talk about colonizing Mars, but with MARVEL even VENUS and CERES can be settled." – Joris Luypaert, founder

#### Performance

Payload to EARTH Orbit / 30 metric tons Payload to Mars Surface / 20 metric tons Up down Ferry Capability @ Mars / 20 – 50 metric tons Total Vehicle weight @ Earth Lift Off / Up to 500 metric ton Dry Weight / 12 metric tons

## MARVEL

"The Most important job is not the initial payload, but getting MARVEL on MARS. It is there that it will start to fully shine".

#### Performance

Payload to EARTH Orbit / 30 metric tons

Payload to Mars Surface / ~10 metric tons

Up down Ferry Capability @ Mars / 20 – 50 metric tons down/up, always, and up to 95 metric ton up on internal propellant + Bladder tanks (300 mton of prop)

Total Vehicle weight @ Earth Lift Off / Up to 500 metric ton

Dry Weight / 12 metric tons

#### NTERPLANETARY PERFORMANCE FROM LEC

#### Moon

Combined with a Neumann Drive @ >14000 ISP the 41 mton vehicle\* can move 23,1 mton from LEO to Moon Orbit (Low Thrust Delta-V of 8), meaning itself and >10 mton of Cargo. This is enough to create an initial Moon Orbit Crewed Outpost.

Combined with a Neumann Drive @ >14000 ISP the 75 mton vehicle\* can move 42,3 mton from LEO to Moon Orbit (Low Thrust Delta-V of 8), meaning itself and 30 mton of Cargo/Propellant. This is enough to land on the Moon or create a fully equipped orbital Moon Station. Refuelling in orbit gives it additional capability.

#### Mars

Combined with a Neumann Drive @ >14000 ISP the 41 mton vehicle\* can move 14 mton from LEO to Mars Orbit (Low Thrust Delta-V of 15), meaning itself and 2 mton of Cargo. It cannot land without refueling.

Combined with a Neumann Drive @ >14000 ISP the 75 mton vehicle\* can move 25,6 mton from LEO to Mars Orbit (Low Thrust Delta-V of 15), meaning itself and 10mton of Cargo/Propellant. This is enough to land on Mars and start producing propellant.

\* : MARVEL can lift 41 metric ton into Low Earth Orbit (LEO) or 17,8 mton to Geo Transfer Orbit (GTO) in a KEROLOX version. A HYDROLOX version lifts 75 metric ton to LEO and 38 mton to GTO.

This means that, depending on the fuel, you can lift an extra payload of about 22 to 53 metric ton into Low Earth Orbit, which could be used to equip MARVEL with internal habitats and create a station-like crewed presence in LEO in one lift. If you leave the droptanks attached, two MARVELS can make a rotating station. The Flash Bainite Steel Construction can take the strain and lift capacity is big enough to allow for the extra mass to equip them with airlocks/mating adapters, etc.

Too good to be true? No, this is a direct result of the one-stage-on-top configuration.

## MARVEL

"Once on the SURFACE of MARS, a single MARVEL can start its job of producing propellant and lifting hundreds of tons of fuel and cargo into Mars Orbit."

#### TYPICAL MARS MISSION SCENARIO INVOLVING TWO OR THREE MARVELS

Combined with a Neumann Drive @ >14000 ISP the 75 mton vehicle (M75) can move 25,6 mton, from LEO to Mars Orbit (Low Thrust Delta-V of 15), meaning itself and +/- 10mton of Cargo/Propellant. This is enough to land on Mars and start producing propellant. MARVEL has multiple engine and landing gear redundancy, which will guarantee multiple up down missions with the same vehicle.

#### Mars:

A) MARVEL ONE is sent to MARS with propellant.
 It leaves the NEUMANN DRIVE in orbit, which can serve as an orbital tug.
 It lands, creates propellant and gets to orbit wih full propellant tanks. All autonomously.

B) MARVEL TWO arrives in orbit with up to 10 mton of payload.MARVEL ONE refuels MARVEL TWO in orbit.Both MARVELS land and refuel.

C) MARVEL THREE arrives at Mars with 10 mton of payload. MARVEL ONE, the oldest, lifts off, delivers 95mton of propellant to orbit and refuels MARVEL THREE. Both MARVELS Land and refuel.

We now have 56 metric tons of Earth Resources on MARS and the three MARVELS will together produce 900 metric tons of Propellant.

We now have multiple choices:

- How many MARVELS serve as a HAB or Surface Propellant Depot?
- The propellant produced serves as radiation protection while on MARS.
- How many MARVELS are kept as an emergency crew lift off?
- How many MARVELS serve as an IN ORBIT FUEL DEPOT/CREW STATION/ORBITAL TUG?
- How many MARVELS solely perform FERRY RUNS?
- Do we send the NEUMANN TUG on interplanetary Ferry Missions to Earth?
- Do we send a MARVEL ROTATING BASE TO MARS?

- Answer: We send more MARVELS and More Cargo.

#### Payload to Mars Surface / 10 metric tons

Performance @ MARS

Payload up Capability / up to 95 metric ton of propellant up if use of bladder tanks (300 mton of prop) 50 metric tons of payload up if it wants to land afterwards, always,

Total Vehicle weight @ MARS Lift Off / Up to 320 mton

Propellant Production / 30 metric tons /month

## MARVEL

**Rotating Space Station** 

Mass in LEO / 80 metric tons or more

Length of two arms / 160 meters

Construction / 2 MARVELS attached via droptanks or 3 MARVELS (shown), up to 5 MARVELS can be combined in a 4 arm configuration Giving a diameter of 164 meters.

Locations / LEO, Moon Lagrange, Mars Low Orbit, Phobos & Deimos,



#### Rotating Space Station → Earth/Moon/ Mars/ Venus/ Asteroid Belt

Two MARVELS create a rotating station in just two launches if you leave the droptanks attached. A Kerolox version would give you 82 metric tons to play with and a Hydrolox version 150 mton. The Flash Bainite Steel Construction can take the strain of the rotation and the lift capacity allows the inclusion of airlocks/mating adapters, etc.

The drawing shows three MARVELS of which one has fully fueled drop tanks. Provided with enough propellant these MARVELOUS BASES can self deploy around various destinations in the inner solar system.

Every gallon of propellant will serve as radiation protection or fuel or water for the crew. The preferred option is to convert the propellant in orbit to water immediately and reconvert it to fuel when required, using electrolysis. This prevents boil off (unwanted evaporation) of propellants.

Safety is enhanced because you always have two or three MARVELS at your disposal to land or pick up crew @ your destination and serve as fully equiped multiyear life boats.

Additional down-up PROPELLANT FERRY missions will only helpt to bring propellant in orbit and add usefulness to the orbital base as a crewed outpost, propellant and cargo depot.

## MARVEL

"Imagine a MARVEL BASE in LEO, Mars Low Orbit, around the Mars Moons Phobos & Deimos, around Venus and around CERES or VESTA."



Drawing: MARVEL Rotating Base 162 meters in diameter. To obtain Earth Gravity it rotates once every 25 seconds.

#### Rotating Space Station

#### 5 Arm Statior

- → 5\* 75 mton in LEO = 375 mton
- → 160 meters in diameter
- Ample power, docking stations
- $\rightarrow$  5 redundant vehicles

#### ocations

Earth/Moon/ Mars / Venus / Asteroid Belt

#### Crew health benefits of artifical gravity

Bone loss eliminated on multi year in orbit stays; prevents damage to eyesight, brain, internal organs. Radiation protection as good as earth atmosphere if ample propellant is provided.

#### New Science

Gradual increase in G from hub to spokes allows for comparative studies to measure the influence of various levels of G on biology and materials.

#### Gravity Force

Anywhere between Moon and Earth Gravity or Microgravity

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## The Solar System





Partners

Neumann Ion Drive / http://neumannspace.cor

Inflatable Propellenat Bladders/ http://www.thin-red-line.com

Reusable Heatshield & structures / Thales Alenia Space, NASA

Rocket Engines / Saffran, Ariane and ULA

Solar Panels / DSS Solar, USA



With the Neumann Drive, MARVEL has a one way DELTA V capability of 15 m/s. This opens up the inner solar System

Yellow: Destinations in reach of MARVEL



## MARVEL



#### MARVEL is an INDUSTRIAL PARTNERSHI

Within the international restrictions on the exchange, export of rocket technology we are able to create a vehicle that can lift off from European, Australian and US soil. This gives our customers access to the best lift off locations for their mission requirements.

We have created an independant legal structure that maximises vertical integration to reduce production and operational costs. This is enabled by the sharehold structure in which our partners hold shares in accordance with their work volume.







## MARVEL



#### FINANCING MARVEL

Is only possible if the vehicle can be made to generate cash in Earth LEO

This will pay for development of extended capabilities

When an individual vehicle has paid for itself, we send it off to MARS for landing and take off testing

We will make this reusable vehicle up to the task

Every earth launch builds confidence in the design

#### **Financial Partners**

Neumann Ion Drive / <u>http://neumannspace.com</u> Inflatable Propellenat Bladders/ <u>http://www.thin-red-line.com</u> Reusable Heatshield & structures / Thales Alenia Space, NASA Rocket Engines / Saffran, Ariane and ULA Solar Panels / DSS Solar, USA

## MARVEL



#### R& D

• Material selection (lightweight heat resistant aerostructure), reusability

• Propulsion (Aerospike + Thermal)

Vehicle Integration

Droptanks and crossfeeding

Vehicle configuration

#### Integration

Industrial Organisation
I aunch Pad Infrastructure

#### Operations

Launch Pad Operations
 Customer Payload Integration

#### Organisation

Project Financing
Legal
Human Resources
Commercial exploita

## MARVEL





#### R & D

- Materials selection (lightweight heat resistant aerostructure), reusability
  Propulsion
- •Aerospike Plug + Thermal >500ISP
- Vehicle Integration & Human ratin
- •Crew Comfort and Health
- Droptank Propellant Crossfeedin
- Vehicle configuration
- Future Capabilities Integration



#### Integration & Testing

- •Vehicle Component Integration
- •Launch Pad Infrastructure
- •Industrial Organisation
- Lesting
- Future Capabilities integration



#### Operations

- Production phase build up
- •Ground Segment
- •Launch Pad Operations
- Customer Payload Integration
- •Human Factors
- •Spacecraft Tracking, communications
- and control
- Deep Space Operations



#### Organisation

- Project Finance
- Legal
- Human Resources
- •R&D Network
- •Industrial Network
- Scientific Network
- •Vertical Integration
- •Commercial Exploitation

## MARVEL Project Management

## MARVEL





#### Joris Luypaert, CEO & Founder

"Traveling into space and establishing a permanent presence on Mars is a lifelong ambition. It feels great to be able to make this happen with our team of dedicated enthousiasts and profesionals through innovation and dedication".

- Joris has been a space enthousiast his entire life. Leveraging his knowledge of the internal workings of international organisations in various roles, he is well equiped to paas on his enthousiasm to both internal and external stakeholders and investors.

Eljoris@hotmail.com



# MARVEL -Tech

## A MARVEL is a MARVELOUS Rocket

Mars Ascent Return Vehicle Earth Lift Off Universal System *(Marvelous)* 

Heralds a revolution in rocket design





Radiation protection with fuel Moon and Mars Capable MARVEL **Reusable Rocket Launcher** Universal Platform **Deep Space Explorer** Single Stage to Orbit Mars Ascent Vehicle Phobos & Deimos surface Base Compart Flexible Solar Panels SpaceX beater 50 KW Solar Power @ Mars **Rotating Space Station** Fuel Abundance Paradigm Interplanetary Ferry Droptanks European Aerospike plug Inflatable Fuel Tanks Forward Mars Base Habitat Orbital Tug Artificial Gravity Cheap Man rated Life Support Drop tanks are corridors for crew Vertical Orbital Fuel Depot Integration Reusable Heat Shield @ Mars Ion & Chem propulsion Flash Bainite Metal Construction Deep Throttling Engines Ultra Low Launch Stack (18m) Propellant Factory through pit launch Autonomous cargo unloading **Rotating Space Station** Wheeled surface mobility Truck like operations



## MANNED MARS MISSONS

Manned missions to MARS have a bottleneck

They need a transportation system between MARS SURFACE and Earth Orbit Cargo Humans

Current Approach Lego Bricks + SLS Heavy lift - Maximum reuse of existing capabilities built for ISS - SLS as better-than-Saturn V replacement - Enabler to throw large masses to MARS

- Landing and lift off remains to be perfected

- Commercial Opportunity for versatile platform



## MASS To Orbit – OLD Approach

### ISS 400MT



ARMADA OF LAUNCHERS – SMALL MODULES (SPACE SHUTTLE / PROTON / ARIANE/ SOYOUZ / JAPANESE H2 / DELTA 4 / ATLAS / FALCON 9 / ULA )





## MASS To Orbit – NEW Approach

## SKYLAB 1973-1979 - SATURN 5 (FINAL)



BIG CHUNKS ON BIG ROCKET : NASA SLS SUPPORT VEHICLES FOR SUPPLY MISSIONS





## MASS BUDGET – MARS ORBIT

### ISS 400MT



## MARS SPACE STATION – 150 MTON LOCKHEED MARTIN PROPOSAL





## MASS BUDGET – MARS SURFACE

### MARS SURFACE STATION 150MT



### MARS ASCENT VEHICLE



magery: Creative Commons



## MARS ASCENT VEHICLE (MAV)

## TYPICAL MAV: FUEL SCARCITY PARADIGM

Choices made to save weight and fuel on descent and ascent

→ Descent and Ascent are separate vehicles

→ Severely Limits functionality and capability

Functions not integrated with other functions

- Earth Launch
- Interplanetary Ferry
- Crew Hab
- Propellant Production
- Cargo Ferry between orbit and surface





## MARS FERRY - Basics

A Mars Ferry is a big truck

Your MAV is your EARTH Launcher (!)

Ferries 20mton objects up and down @ MARS

Reusable engines

Reusable heatshield under Mars Conditions (Pica X, Woven TPS @ NASA)

- Independent fuel manufacturing on Mars
- Autonomous unloading
- Multi-use-platform

Human rated and Human tended cargo platform





## MARS FERRY – Revolutionary Paradigm

### Abundance mindset

Fuel is easy to produce on Mars from atmosphereReusable tech is good enough today for Mars environment (!)(Heatshields e.g.PICA-X are reusable under Mars Conditions)Decimates mass budget to be lifted from Earth and (!) from Mars

### Opens up destinations

between Mars Low Orbit & Mars Surface (Chemical rocket engines) between Mars Low Orbit & Mars High Orbit (fuel efficient Ion prop module) between MLO and Phobos & Deimos Outposts (fuel efficient Ion prop module) between MLO & Earth/Moon Orbit (Ion Prop + Chemical combo)
# MARS FERRY Proposal: MARVEL

#### Starts from an abundance mindset

- Fuel is easy to produce on Mars from atmosphere
- Reusable tech is good enough today (!
- One capable vehicle with many functions
- Mars is a benign environment to engineer for

#### Designed into a multi-use platform

- Cargo truck
- Human up-down-up
  - (no separation between ascent & descent function <u>because</u> fuel is easy to produce)
- Human Interplanetary truck
- Fuel Depot (Long term)
- Human Rotating Space Station
- Earth Self Launch Capable



# MARVEL INNOVATES

- A. Configuration: Engines on top + Droptanks on botttom + Thermal rocket → above 500 ISP barrier
  - 1. Radical improvement in performance / Weight saver
  - 2. Radical improvement of Launch Pad operations.
  - 3. Development path to 600-700 ISP with chemical-thermal rocket hybrid
- B. Universal platform (replaces up to 13 independent vehicles)
- C. Deep Space and LEO capability on a small platform
- D. HERCULES: <u>Homemade European Reusable Capability for Launching to and Exploring Space</u>
- E. Commercial or mixed public-private
- F. Metal construction instead of composites (Flash Bainite)



#### MARVEL INNOVATIONS

# A. 1. Configuration exponentially increases performance

Engines on top + Droptanks on botttom + Aerospike

#### Inspiration: Dr. Robert H. Goddard

- He could not make it work (instability)
- Today we have fast computers to regulate thrust (stability guaranteed)
- Reusability has been proven (Delta Clipper / Spacex / Blue Origin / Morpheus / Pixel)

#### Advantages:

- only one set of engines/ no engine staging events
- Weight saver
- Payload increase is hight
- Deep Space with one vehicle
- Uses cheap lightweight central droptanks
- Most expensive part is Reusable
- Drastic performance improvement on a small vehicle



#### MARVEL INNOVATIONS

# A. 2. Launch Pad operations improve radically



## SpaceX - F9 / Soyouz

Mobile, erecting launch tower →Erects on launch site

☺ Low cost infrastructure☺ No access to payload on pad



# NASA - SLS

Above 100 meter launch tower→ Permanent structure

③ Guarantees last minute access
 ※ Expensive to build
 ※ Expensive to Maintain



## LSS- MARVEL

18 meters high MARVEL→Launch pit for droptanks

③ Guarantees last minute access
③ Low cost
③ Additional increase in safety



# A. 2b. Launch Pad operations improve radically

Falcon 9 Falcon Heavy Compared to MARVEL (To scale) 



# A. 2c. Change of fuel? Dig a deeper pit for a longer Droptank

Falcon 9 Falcon Heavy

Compared to

MARVEL VERSIONS

(To scale)





# A. 3a. Marvel breaks the 500 ISP barrier

### MARVEL AEROSPIKE DOUBLES AS a hafnium carbide HEAT EXCHANGER



Exhaust of rocket engines heats monopropellant Hydrogen to 1800 °C to get 900 ISP.



This is done via the conformal heat exchanger on the ramp and sleeve



Separate Thermal thrusters expel monohydrogen parallel to standard rocket engines

Combined 'normal' rocket engines exhaust and Thermal rocket exhausts will exceed 500 ISP.

Possible because of recuperation of lost thermal energy of the bipropellant engines

In MARVEL a large fraction of it is no longer'lost' thermal energy but converted in more efficient exhaust (900 ISP)



#### MARVEL INNOVATIONS

# A. 3b. Marvel breaks the 500 ISP barrier

°C

# pulsione wireless a microon





#### MARVEL STEALS the old thermal rocket idea

If Falcon 9 comparable output = 27 GW of energy, a large fraction is not converted to kinetic energy but 'lost' as thermal energy (2/3ds)

MARVEL AEROSPIKE DOUBLES AS a hafnium carbide HEAT EXCHANGER to heat Hydrogen to 1800 °C to get 900 ISP. The combined 'normal' rocket and Thermal rocket hybrid-output WILL break the historic 500 ISP barrier for non nuclear rockets and more probably will exceed 700 ISP.

This would mean a dry mass fraction (payload + structure) of 27% at a Delta V of 9 and ISP of 700; or 22% @600ISP and 16,5% @500 ISP, where it is today 10-13,5% (@400 to 450). Remember 5% of total mass usually is used op for dry rocket structure. MARVEL, for the same liftoff wheight, thus inreases payload mass up to three to fourfold... A 500 mton vehicle would lift 138mton...of which a 115mt could be payload.

Escape dynamics only needed 900MW of microwave beamed power to drive their heat exchanger and thermal rocket to get 900 ISP from hydrogen as a monopropellant at 1800

### MARVEL INNOVATIONS

# B. 1. Universal Platform MARVEL

- 1. Reusable Earth Lift off (self launch)
- 2. MARVEL is the upper stage & Reusable Ferry
- 3. Interplanetary stage (ion prop mod)
- 4. Crew/cargo vehicle
- 5. Reusable lander
- 6. Propellant plant
- 7. Mars Ascent Vehicle (MAV)
- 8. Earth Return vehicle from Mars (ERV)
- 9. Reusable heat shield
- 10. Weels for surface mobility
- 11. Surface Habitat (HAB)
- 12. Orbital Fuel Depot
- 13. Orbital Rotating Space Station

# REPLACES up to 13 VEHICLES

- 1. Reusable Rocket Launcher
- 2. Upper Stage
- 3. Interplanetary Stage
- 4. Crew/Cargo Module
- 5. Descent stage + Ascent Stage
- 6. Propellant plant
- 7. Mars Ascent Vehicle (MAV)
- 8. Earth Return vehicle (ERV)
- 9. Heatshield
- 10. Surface Mobility
- 11. Surface Habitat (HAB)
- 12. Orbital Fuel Depot
- 13. Orbital Rotating Space Station



# B. 2. Exponential increase in operational versatility





# C. Deep Space Ferry and LEO capability

# DEEP SPACE FERRY TRUCK

### Interplanetary Ferry

- 1. Mars Surface Ferry (chemical)
- 2. Moon Surface Ferry (chemical)
- 3. Mars Interorbital Ferry (ion prop)
- 4. Moon-Lagrange Ferry (ion prop)
- 5. Venus Orbital Ferry
- 6. Asteroid Belt Ferry (Ceres / Vesta)

All are reusable operations in Mars/Moon environment

= Paradigm shift



# LEO

- 1. Space Station
- 2. Fuel Depot
- 3. Rotating Station if coupled
- 4. Cargo Up-Down Capability

Payload Mass depends on length and weight of Droptanks; LEO Above 20 mton (@Delta V 9kms, 350 ISP) GTO Up to 12 (@ Delta V 12kms, 450 ISP)

#### MARVEL INNOVATIONS

# D. HERCuLES: Homemade European Reusable Capability for Launching to and Exploring Space

- We need a SpaceX beating rocket vehicle
  - MARVEL beats SpaceX Falcon 9
    - On cost
  - On Performance
  - On versatility
  - MARVEL is a SpaceX Red Dragon killer (Mars version)
  - On cost
  - On performance
  - On versatility

-Europe has all the industrial know how to do this

-Could use a versatile platform





# E. Commercial or mixed public-private

# European Commercial Vehicle

- 1. Preferred
- 2. New for Europe
- 3. Vertical Integration decimates cost (SpaceX, Blue Origin as examples)
- 4. Cheaper acces to space benefits every actor
- 5. European market knows legal obstacles but these can be overcome

# Public-Private

- 1. Less preferred
- 2. Business as usual
- 3. Leads to more expensive vehicle
  - in construction
  - in maintaining industrial network
  - in operation
  - Political costs (delays, juste retour, sabotage)
- 4. More expensive access to space for everyone
- Industrial networks exist (ESA, e.a.) (But commercial benefits evaporate)

MARVEL INNOVATIONS

# F. Flash Bainite Steel instead of composites

# SpaceX: Labour intensive production

- 1. Currently Alu construction
  - First stage 20 mton
  - Second Stage 30mton
  - Total dry weight 26mton (5,9% of total mass)
  - Propellant Mass 396 mton
- 2. Wants to switch to Carbon Fiber composites
  - Higher cost warranted by reuse
  - Typically 40% reduction in dry mass
  - Leads to ~16mton dry mass (3,6% of total mass)

Source: <u>http://www.nextbigfuture.com/2016/08/spacex-plans-to-use-lot-more-carbon.html</u>

# **<<<** MARVEL: Car like manufacturing

- . Chooses Flash Bainite construction
  - 1600 to 2100MPa steel (!)
  - Strenght due to a heat treatment innovation
  - 30% lighter than Alu and higher strength
  - Ductile, Weldable, Hydroformable, Stampable at room temp !
  - Steel can be hardened after it has been roll formed (!)
- 2. Easier to manufacture, reuse, repair, than the very labour intensive composites
- 3. Even at 16mton dry weight, still much cheaper to operate and produce

(upper stage/ droptanks)

### http://www.flashbainite.com/



# MARVEL – Multi use Platform

Mars Ascent

Reusable Vehicle

Earth Lift Off

Universal System

Marvelous -SSTO: Single Stage To Orbit -SSTORMER: Single Stage To Orbit Return from Mars and Earth Return -FTR: Forward Thrusting Rocket

### MARVEL REPLACES VEHICLES

## MARVEL

- 1. Reusable Earth Lift off (self launch)
- 2. MARVEL is the upper stage & Reusable Ferry
- 3. Is the interplanetary stage (ion prop mod)
- 4. Is crew/cargo vehicle

ONESTAGETOSPACE

- 5. Is reusable lander
- 6. Is propellant plant
- 7. Is ascender
- 8. Is Earth Return vehicle
- 9. Has a reusable heat shield
- 10. Has weels for surface mobility
- 11. Surface Habitat
- 12. Orbital Fuel Depot
- 13. Orbital Rotating Space Station



# REPLACES UP TO 13 VEHICLES

- 1. Reusable Rocket Launcher
- 2. Upper Stage
- 3. Interplanetary Stage
- 4. Crew/Cargo Module
- 5. Descent stage
- 6. Propellant plant
- 7. Ascent stage
- 8. Is Earth Return vehicle
- 9. Heatshield
- 10. Surface Mobility
- 11. Surface Habitat
- 12. Orbital Fuel Depot
- 13. Orbital Rotating Space Station



# 1. Reusable Earth Lift off (self launch)

## TECH

- a. SpaceX-like reusability concept
- b. Aerospike conformal config.
  - a. 30% increase in fuel efficiency
  - b. Round plug (Firefly) preferred above Linear XRS-2200 (NASA, X-33)

- c. Central plug (droptanks + ramp)
- d. Hafnium Carbide (melts at 3900 C°)
- e. Aerotherm or PICA-X on droptanks (density 280 kg/m<sup>3</sup>)





# 2. Upper stage & Reusable Ferry

### TECH

- a. One stage has all the vehicle engines
- b. No engines are ejected and lost
- c. Specs:
- 18m high
- +8,5m outer diam
- +3,66m inner diam
- 12mton dry
- 112mton wet
- 45mton payload (mission outfit dependant)





# 3. Interplanetary stage (ion prop mod)

## TECH

# a. Ion Propulsion 50kw-100 range

- a. Nasa
- b. ESA
- c. Commerical
- b. 3mton module (uses MARVEL)





# 4. crew/cargo vehicle

### TECH

- a. Modular outfitting optimized for crew or cargo role
- b. 20mton average payload landing capacity
- c. Crew Inflatable modules Water walls Life Support

#### d. Cargo

Minimal Life Support More open Space Propellant production optimized

#### e. Mixed

Minimal Life Support Uninflated crew module included

f. Rotating Space Station Central node to receive rotating arms

## PICTURE

### 20MTON AVERAGE PAYLOAD CAPACITY





# 5. Reusable lander

## TECH

- a. SpaceX-like reusable engines
- b. Redundancy
- c. Methane engines (no deep cryo issues)
- d. Reusable retracting landing legs
- e. Reusable heat shield in Mars conditions Pica X, other
- f. Reusable foldable solar panels (DSS Solarosa, USA)
- g. Long term storage of Methane (big molecule)
- h. Propellant plant

From Martian atmosphere (WAVAR + SABATIER Tech)





# 6. Propellant plant

## TECH

# Methane engines (CH4)

## a. WAVAR tech (1970'ies)

- ~ Dehumidifier with zeolite bed
- ~ Harvests water vapor from Mars Atmosphere
- b. Sabatier tech Converts Martian CO2 atmosphere to CH4
- c. Internal and or external storage Enables Fuel depot in orbit Enables Fuel depot on surface



# 7. Mars Ascent Vehicle (MAV)

### TECH

# Methane engines (CH4)

## a. 9 Deep throttlable engines

Operate in Earth and Martian conditions Mars = Earth at 30,000 meters above sea level Throttle to 10% of thrust

### b. Propellant abundance on MARS

prevents need to separate lander from ascender (no need to save on propellant)

### c. Triple redundancy of engines

Enables long term autonomous reuse with multiple engine out



PICTURE

# 8. Earth Return Vehicle (ERV)

### TECH

### Methane engines (CH4)

a. 9 Deep throttlable engines Operate in Earth and Martian conditions Mars = Earth at 30,000 meters above sea level Throttle to 10% of thrust

#### b. Propellant abundance on MARS

prevents need to separate lander from ascender (no need to save on propellant)

#### c. Triple redundancy of engines

Enables long term autonomous reuse with multiple engine out

### d. Optional refuelling @ Mars Orbital Depot





# 9. Reusable Heat Shield

### TECH

# Reusable in Mars Conditions

- a. More benign conditions Less dense atmosphere → less heating → extended lfe
- b. Heritage materials are sufficient
  - a. PICA and PICA-X (NASA)
  - b. Woven TPS (Carbon-Carbon a.o. NASA)
  - c. ESA IXV-programme
- c. Optional refuelling @ Mars Orbital Depot





# 10. Wheels for Surface Mobility

TECH Electric Drive Lightweight

Optional







# 11. Surface Habitat (HAB)

### TECH

Basic Life Support Large Internal Volume Basic Internal Layout Redundant Airlocks and Cargo Ramp Radiation Shielding (Fuel or Water Wall)

→ Even Without extra habs it can serve as a minimal Crew Hab



# 11. Essential Part of Mars Base





# 12. Orbital Fuel Depot

### TECH

Autonomous Refuelling (ESA/NASA/ROSCOSMOS/JAXA/CNSA)

Long Term Storage Flexible Storage Tanks (Thin Red Line Aerospace) CH4 fuels are stable in Space environment





# 13. Orbital Rotating Space Station

TECH
Steel Construction of MARVEL
→ required tensile strength
→ Flash Bainite 1500 (Lighter than Alu/ Stronger than Steel)

Dual use Propellant tanks (airlocks/corridors)

PICTURE

: : : : .



# 13. Competition & Historic Precursors

### CURRENT DEVELOPMENTS

2016 Ixion Initiative Team ( NanoRacks, Space Systems Loral, United Launch Alliance (ULA))

- Study to reuse rocket stages as habitats under the NASA NEXTSTEP-2 Public Private second Next Space Technologies for Exploration Partnership

- "Our plan is to dramatically lower the proposed costs for habitats to allow for the largest customer base, both commercial and government," said Jeffrey Manber, CEO of NanoRacks, in a press release. "With Loral and NanoRacks working together, we have the knowledge base to assure a solid commercial use of tomorrow's habitats via re-purposed ULA Centaur platforms." Read more at

Source: Press release: August 12, 2016, <u>http://nanoracks.com/deep-space-habitats/</u>





# Further Reading

### NASA Press Release

March 30, 2015 (RELEASE 15-054)

### NASA Announces New Partnerships with U.S. Industry for Key Deep-Space Capabilities

"Building on the success of NASA's partnerships with commercial industry to date, NASA has selected 12 Next Space Technologies for Exploration Partnerships (NextSTEP) to advance concept studies and technology development projects in the areas of advanced propulsion, habitation and small satellites.

Through these public-private partnerships, selected companies will partner with NASA to develop the exploration capabilities necessary to enable commercial endeavors in space and human exploration to deep-space destinations such as the proving ground of space around the moon, known as cis-lunar space, and Mars."

http://www.nasa.gov/press/2015/march/nasa-announces-new-partnerships-with-usindustry-for-key-deep-space-capabilities



# MARVEL – Access entire MARS environment

MARVEL FERRY DESTINATIONS

- 1. Mars Surface
- 2. Mars Low Orbit
- 3. Mars Moons Deimos/Phobos
- 4. Mars High Orbit
- 5. Earth Return to Moon Orbit (Luna)
- 6. Earth Retun to Earth LEO

MARVEL FUNCTIONS Crew/Cargo Ferry Interplanetary Ferry Fuel Depot in Moon/Mars Orbit Fuel Propellant production on Mars (atm) Earth LEO Cargo Launcher Rotating Space Station – LEO/Moon/Mars Surface Habitat (Moon/Mars) Deep Space Ion Prop. Exploration



# MARVEL – Reusable Vehicle

Why?

Truck like functionality is revolutionary enabler (cf. C-130 Military Plane)

Doable

Spacex // Blue Origin

Design for it and reap all the future benefits

One vehicle platform replaces and combines functions of 11 other platforms => Design Marvel and you need only one design cycle instead of 5 competing vehicles



# MARVEL – Earth Lift Off

Single-Stage-to-Orbit with Droptanks on the bottom (technically a stage-and-a-half)

### Why?

- 1. One engine stage at top replaces up to three engine stages (max. reuse/cost reduction)
- 2. Only shedded weight are cheap droptanks (length/weight/nr. varies cf. mission)
- 3. Heat and vibration are no longer a technical problem (well known materials)
- 4. Extra thrust can be added on bottom of droptanks (3,66m diam, cf. Falcon F9 first stage)
- 5. Benefits of Aerospike (15 to 30% increase in fuel efficiency)
- 6. One MARVEL for all LEO and interplanetary missions
- 7. Launch Pit instead of Launch tower for easy last minute access to payloads (Low height)



# MARVEL – Why do we need it?

### MARKET CAPTURE

It is a low cost capability that a future commercial competitor will develop anyway,

... so why not be the first and capture the market?

Reusability is already part of the technological State of the art, no excuse not to do it.

Flexible Modular platform design that allows for incremental additions of both propulsion tech and internal tech

- Engine and ramp mounts are interchangeable
- Internal mounting points for hardware (air locks, inflatable habs, crew pods, hangar doors, furniture, electrics, )

# MULTIPLE COST REDUCTIONS

- 1. One vehicle replaces multitude of vehicles Lower number of design cycles (less engineering teams)
- 2. Can consequently be produced in higher volumes
- 3. Reusability advantages
  - 1. Number of vehicles to be produces
  - 2. Lower operational costs/mission
  - 3. Each added vehicle leads to exponential growth in number of missions that can be flown
- 4. Leads to iterative improvements

The design skips multiple successive generations of competing designs simply by using a smarter cost reducing integrated configuration
## MARVEL MARKET

## Effect of the CubeSat revolution





## MARVEL MARKET

Effect of the CubeSat revolution



## MARVEL MARKET





# MARVEL GROUND OPERATIONS

# MARVEL mates with DROPTANKS Launch pit up to 80m deep - Volume for Droptanks Integration above launch Pit Flame trench



(8,5 m diam x 18 m)

# MARVEL

Mars Ascent Reusable Vehicle & Earth Launcher







#### Marvel Interior

(8,5 m diam x 18 m)

#### MARVEL

Mars Ascent Reusable Vehicle & Earth Launcher



Upper Deck: Inflated Hab / Cargo Middle Deck: Pressurized Garage / Airlock corridor

Airlock corridor Rotating station Connector Node

Lower Deck: Propelant Tanks, Power Avionics / Storm Shelter Core

Aerospike plug & Engines Surround lower part of Storm Shelter

MARVEL Mars Ascent

Reusable Vehicle & Earth Launcher

18m x 18m 8,5m ø

> Droptanks 60-80m h, 3m66 ø

ORMER

Single Stage To Orbit Reusable on Mars and Earth Return



ONESTAGETOSPACE







# MARVEL

Creating an Artificial Gravity Environment over 2 or 3 Vehicles,

Marvel offers ample internal Space for Crew, Cargo and Partial G experiments Easy structural maintenance

While retaining its versatile uses

18m x 18m 8,5m ø





# Overal Architecture Composite constellation

# Small subtitel : 4 launches



Mars

Mars Orbit

Moon Orbit

Earth Orbit

0/

Earth

MARVEL FUEL DEPOT ON GROUND & IN ORBIT





Reusable Heatshield (in Mars conditions)

Corridor, airlock, potential rotation arm connector node

& Airlock

Up to 9 legs, Wheeled (redundancy & Mobility)



#### CARGO MISSIONS

On mission where time element is not critical, an ion tug can be put in place of a Storm shelter.

Has its own solar panels but can use MARVEL's

On an earlier mission this can test all propulsive modes



ONESTAGETOSPACE

Ion /electric Propulsion Module Stays in orbit



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On mission where time element is not critical, an ion tug can be inserted in place of a Storm shelter.

On an earlier mission this can test all propulsive modes



Ion /electric Propulsion Module Stays in orbit





#### MARVEL PROPELLANT FERRY

Multiple deep cryo Bladder Tanks are stored folded and can be filled to:

- refuel an in orbit depot
- create a ground depot
- Standard tanks hold 80-100 TON
- With bladder tanks total of 280mton
- Drops off up to 95 mton in orbit
- Liftin off at 300mton wet allows it to ferry 40ton of payload to Mars surface





# MARVEL AND BASE TO SCALE

e A

- Inflatable habs

A

- NASA Surface Exploration Vechicle (SEV)
- 24m long ramp (6 segments)
- Landing legs have wheels with e-motors

# MARVEL AND BASE TO SCALE

When a MARVEL reaches the end of its usefull life as a FERRY VEHICLE it does not have to be discarded,

ONESTAGETOSPACE

- they can be Rolled into position and connected to serve as pressurized quarters
- and/or Continue Propellant and Power production



# MARVEL AND BASE TO SCALE



# MARVEL DEMO & HUMAN RATING AT MARS



MARVEL FUEL DEPOT ON GROUND & IN ORBIT





MARVEL LEO ORBITAL BASE





MARVEL MOON LAGRANGE ORBITAL BASE







# MARVEL MOON L1 ROTATING STATION READY FOR TRIP TO MARS







# MARVEL DEMO: SSTO AT MARS, PROPELLANT PRODUCTION & HUMAN RATING





MARVEL MARTIAN PROPELLANT DEPOT GROUND PRODUCTION & IN ORBIT REFUELING





MARVEL LEO ORBITAL BASE

Mars

Mars Orbit

Moon Orbit

Earth Orbit

Earth





# MARVEL MARS ORBITAL BASE





## MARVEL: Moon Lagrange or RDO Rotating Station, Mars Ready option








N	ARVFI Radiation protection with fuel Moon and Mars Capable
	Reusable Rocket Launcher
	Universal Platform Single Stage to Orbit Deep Space Explorer
Com	Phobos & Deimos surface Base Mars Ascent Vehicle
	Triple redundant Thrust 50 KW Solar Power @ Mars Rotating Space Station
Sba	Fuel Abundance Paradigm Interplanetary Ferry Droptanks
Eur	opean Aerospike plug _ Inflatable Fuel Tanks
	orward Mars Base Habitat Orbital lug Artificial Gravity
Che	ap Man rated Life Support Drop tanks are corridors for crew Vertical
Deep	Reusable Heat Shield @ Mars
Deep	FIASH BAINTE METAL CONSTRUCTION
Αι	tonomous cargo unloading Ultra Low Launch Stack (18m) <b>FIOPEIIAIIL FACLOLY</b> through pit launch
Tru	ck like operations Rotating Space Station Wheeled surface mobility





# SLS BLOCK 2, 130T LOE, 45 MOON

























## VIER Interne Niveaus









## VIJF Interne Niveaus



### **VIER Interne Niveaus**







### VIJF Interne Niveaus



































































Radiation protection with fuel Moon and Mars Capable MARVEL Reusable Rocket Launcher ONESTAGETOSPACE Universal Platform **Deep Space Explorer** Single Stage to Orbit Mars Ascent Vehicle Phobos & Deimos surface Base Compart Flexible Solar Panels SpaceX beater 50 KW Solar Power @ Mars **Rotating Space Station** Fuel Abundance Paradigm Interplanetary Ferry Droptanks European Aerospike plug Inflatable Fuel Tanks Forward Mars Base Habitat Orbital Tug Artificial Gravity Cheap Man rated Life Support Drop tanks are corridors for crew Vertical Orbital Fuel Depot Integration Reusable Heat Shield @ Mars Ion & Chem propulsion Flash Bainite Metal Construction Deep Throttling Engines Ultra Low Launch Stack (18m) Propellant Factory through pit launch Autonomous cargo unloading **Rotating Space Station** Wheeled surface mobility Truck like operations