Investigating traction system development for lunar mobility

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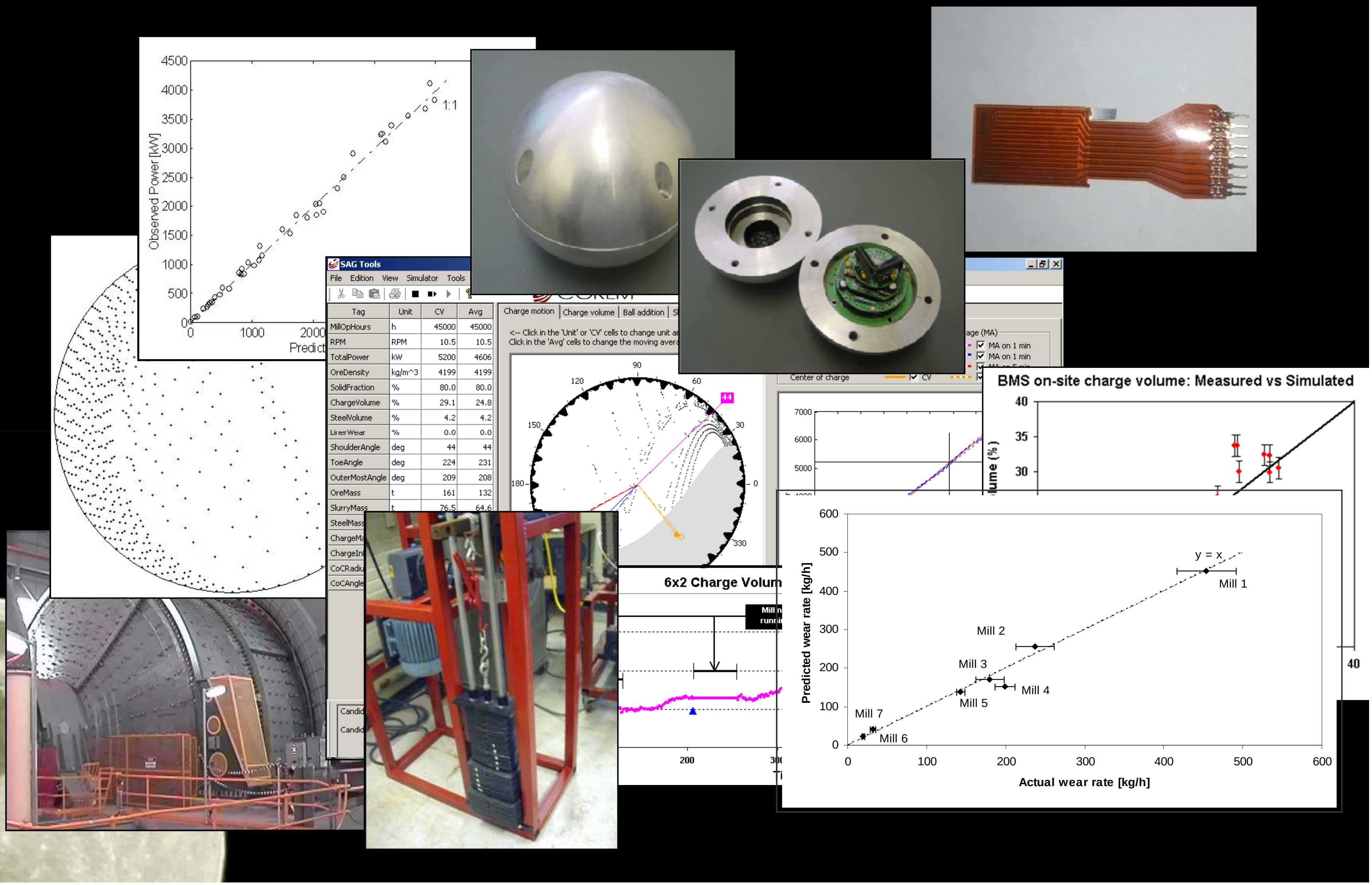
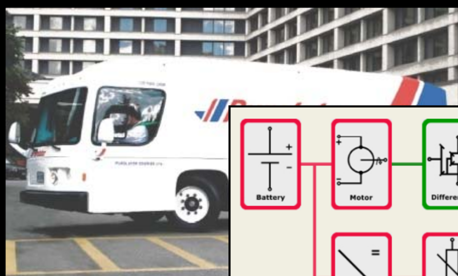
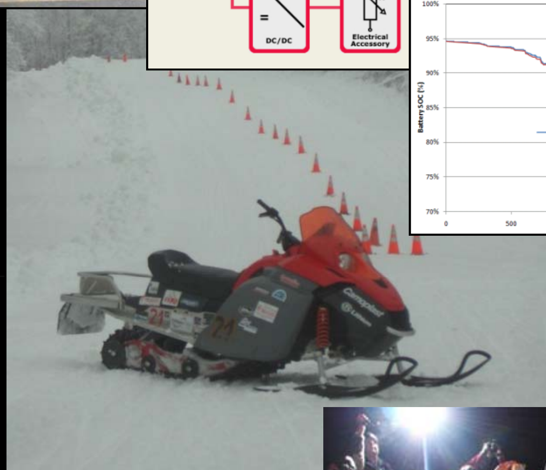
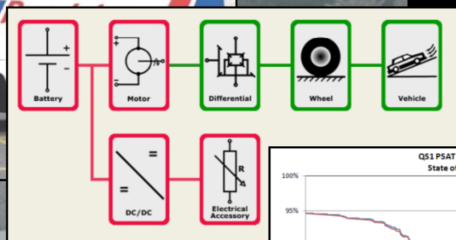
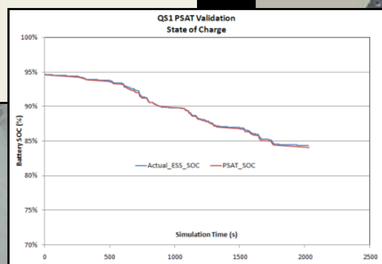
Rock

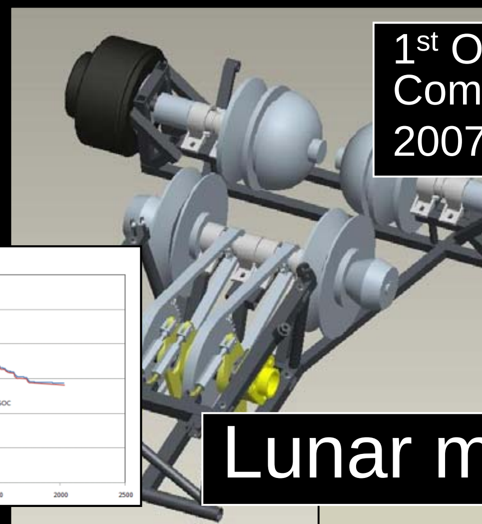


Observed Power [kW]
1:1
SAG Tools
File Edition View Simulator Tools
Tag Unit CV Avg
MillOpHours h 45000 45000
RPM RPM 10.5 10.5
TotalPower kW 5200 4606
OreDensity kg/m^3 4199 4199
SolidFraction % 80.0 80.0
ChargeVolume % 29.1 24.8
SteelVolume % 4.2 4.2
LinerWear % 0.0 0.0
ShoulderAngle deg 44 44
ToeAngle deg 224 231
OuterMostAngle deg 209 208
OreMass t 161 132
SlurryMass t 76.5 64.6
Charge motion
Charge volume
Ball addition
<-- Click in the 'Unit' or 'CV' cells to change unit
Click in the 'Avg' cells to change the moving avera
Center of charge
MA on 1 min
6x2 Charge Volum
BMS on-site charge volume: Measured vs Simulated
y = x
Mill 1
Mill 2
Mill 3
Mill 4
Mill 5
Mill 6
Mill 7
Predicted wear rate [kg/h]
Actual wear rate [kg/h]

Roll

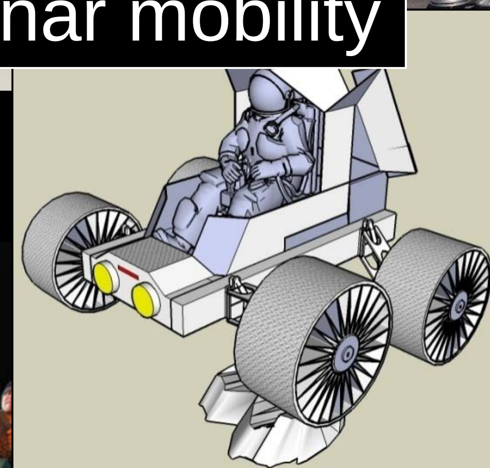









1st Overall – Hybrid Formula Competition
2007, 2008

Lunar mobility




Electric motor dyno


- 1st Overall – Clean Snowmobile Challenge, Zero – emission category
- Best Design 2007
- Carried Olympic Flame Whistler 2010

Introduction

Facilities

- virtual
- physical

Wheel concepts

iRings

Conclusions

Let's Rock n' Roll!

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Introduction

A project was initiated through the Partnership Support Program of the Canadian Space Agency in partnership with the Neptec Design Group and a Natural Science and Engineering Research Council collaborative research and development program that addressed the general goal

…focus on the definition, development and validation of a compliant wheel design methodology which would be used to evaluate and compare the feasibility of different wheel configurations, steering and suspension strategies, and traction designs.

Introduction

Goal of this presentation:

1) Provide an overview of the facilities developed,
2) Overview some of the concepts developed in the literature,
3) Present one of the concepts and the results of initial performance evaluation.

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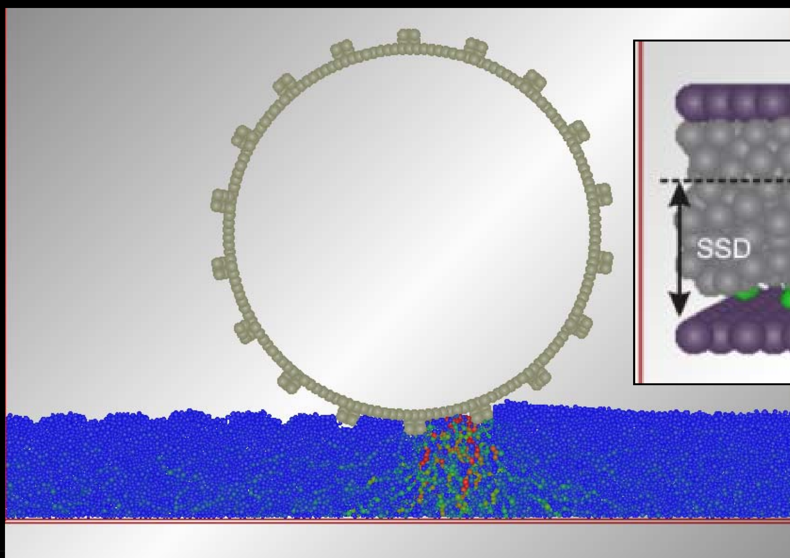
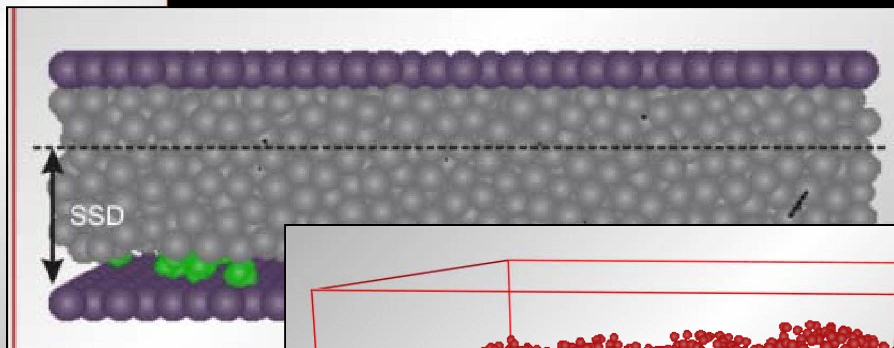
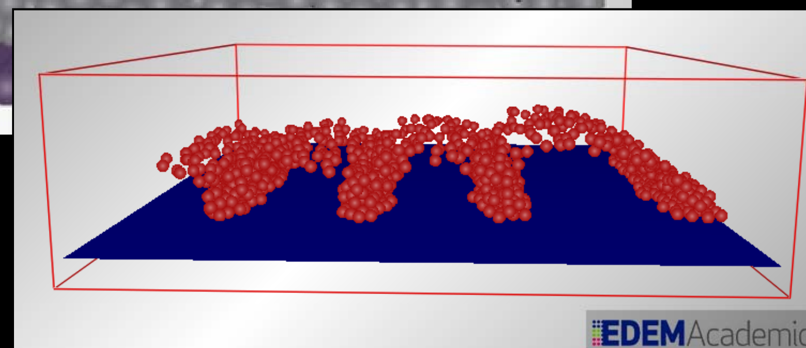
Facilities - virtual



Robin Briend



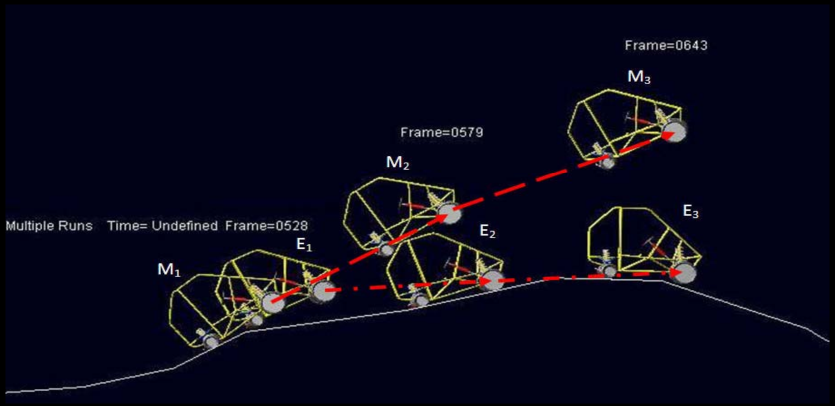


Nima Gharib

strategies combining multi-objective optimization (MOO) and multi-disciplinary design optimization (MDO)

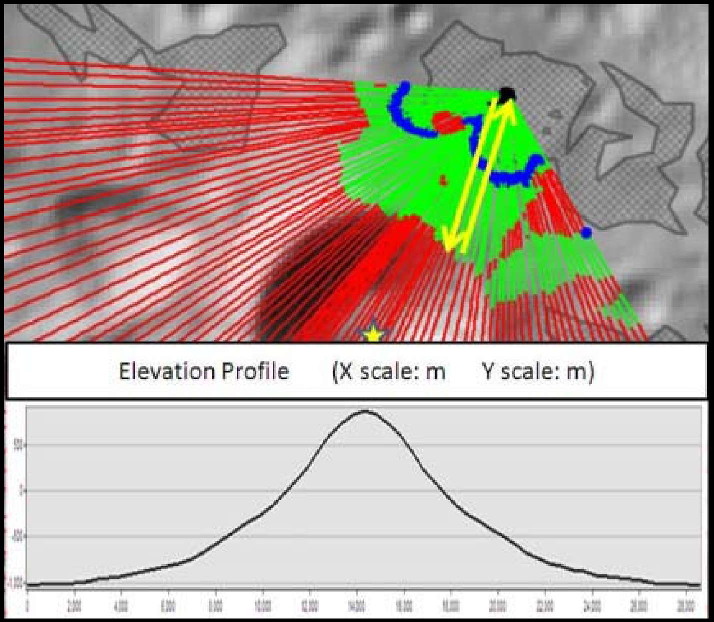
Mic Faragalli

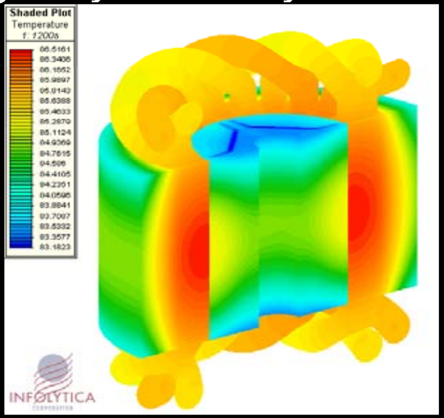
Facilities - virtual



ADAMS simulation of rover in terrestrial and lunar gravity – Dan Oyama

Powertrain simulation as a function of lunar topology (Simon Ouellette)





Motor modelling and simulation (Lowther lead)

Plus real-time simulations using Vortex in collaboration with CMLabs (Kovecses lead)

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Facilities - physical

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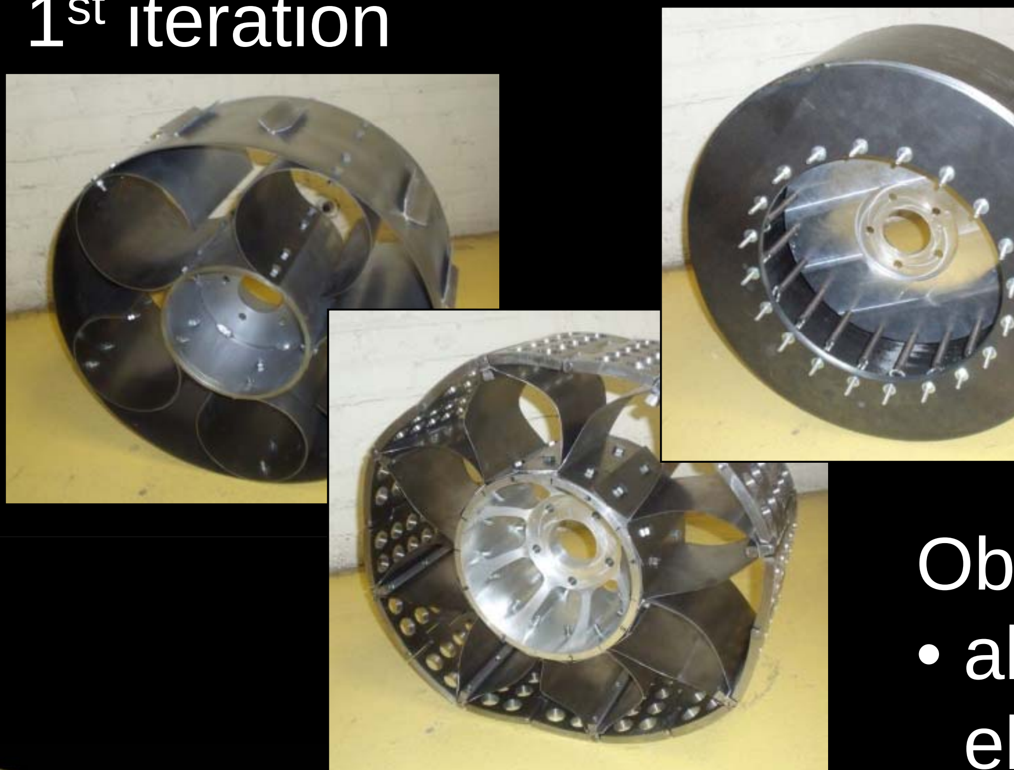
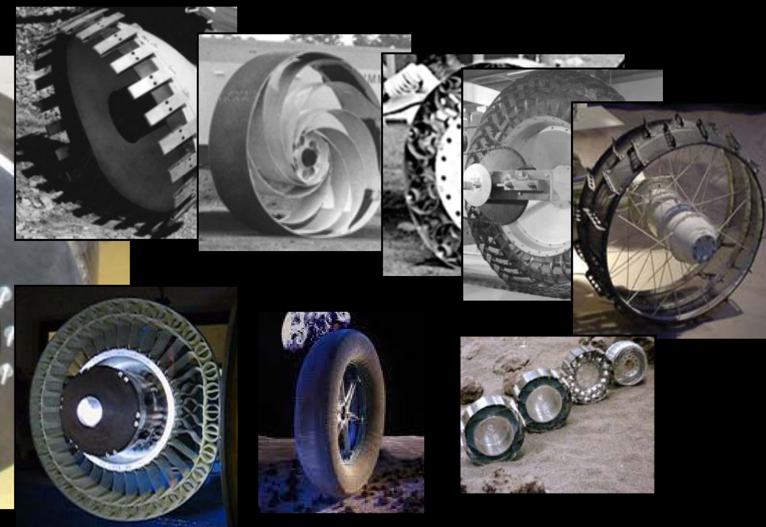
Wheel concepts

1st iteration





Observations:

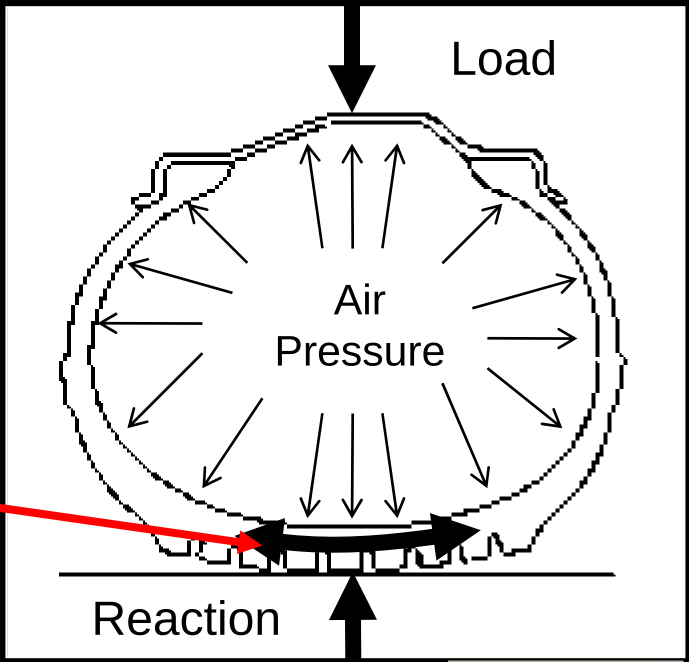
- all of these wheels are elastically compliant,
- elasticity being limited by plastic failure.

Wheel concepts

- What about dampening or energy dissipation or plastic compliance?
- Would the inclusion of some energy dissipation in a wheel be of benefit in lunar mobility either by decreasing the amount of shock transmitted to the vehicle or by allowing higher vehicle speeds?
- Would it contribute to simplifying suspension system design?

Current designs for lunar applications replace air and membrane by structure.

Tension in tire membrane



However, what if membrane was replaced by metal fabric that would only work in tension?
(chain-mail, wire mesh, etc.)
What if air was replaced by multiple load bearing materials?
(ceramic beads, pebbles, regolith, etc.)

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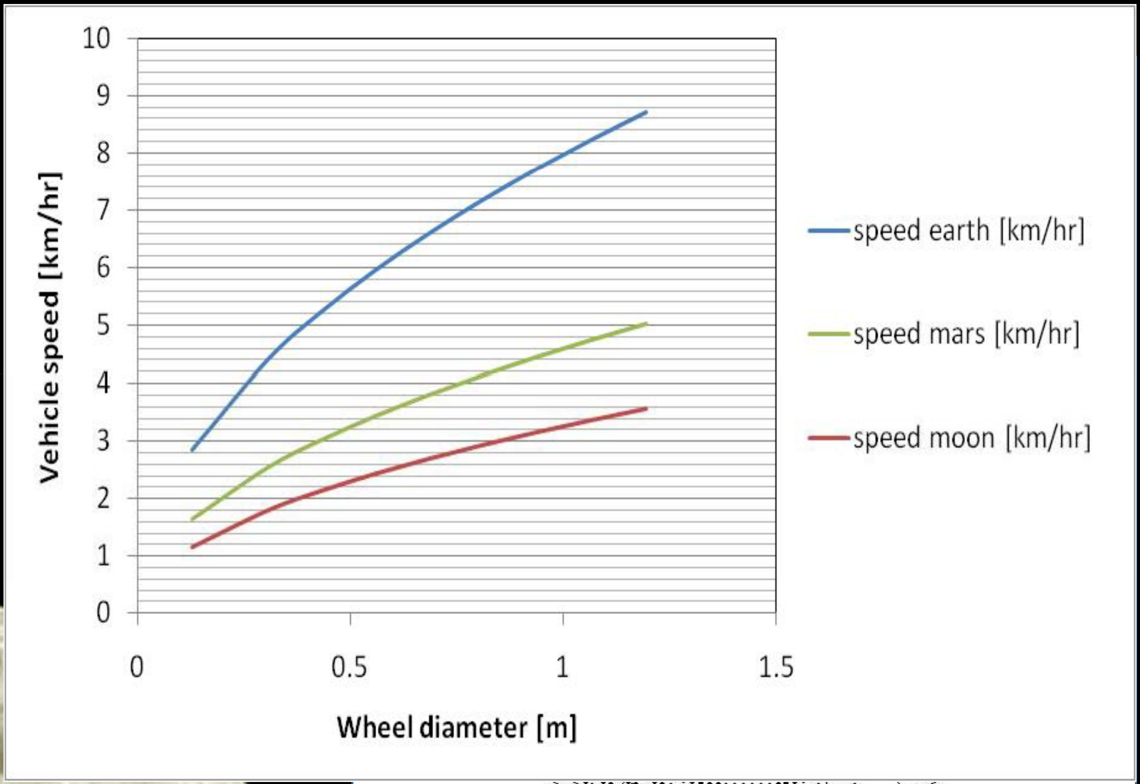
Wheel concepts

Some inspiration from the mining industry?

$$\omega = \sqrt{\frac{g}{R}}$$



Mill critical speed defines the speed at which a mill charge will centrifuge.

This same relationship can be used to determine the speed at which particulate filled tires will centrifuge.

We can expect that particulate filled wheels will stiffen with increased centrifugal forces caused by increased speeds.

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iRings

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iRings

From idea to prototype

V1 – the bean bag (Spring 2009)

V2 – 22" diameter fabric wheel (summer 2009)

iRings

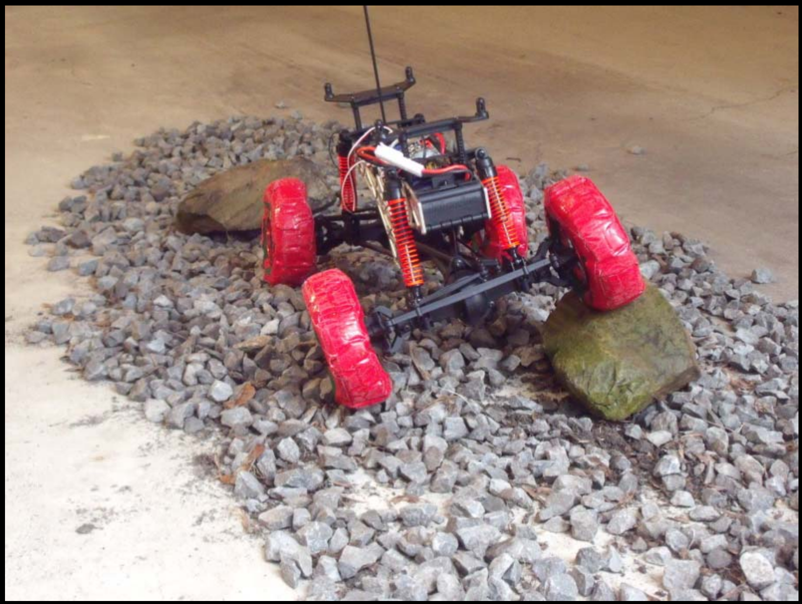
From idea to prototype

V3 – the dried peas filler and duct tape (October 2009)

iRings

From idea to prototype

V3 – the dried peas filler and duct tape (October 2009)



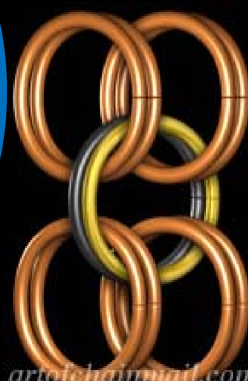
iRings

From idea to prototype

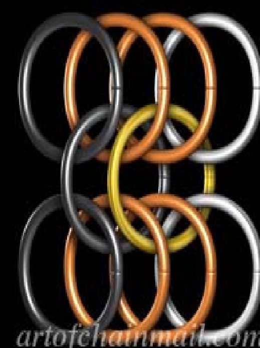
V4 – 5” diameter wheel in stainless steel chainmail and delrin (November 2009)

Chainmail patterns

4 in 1 chainmail pattern

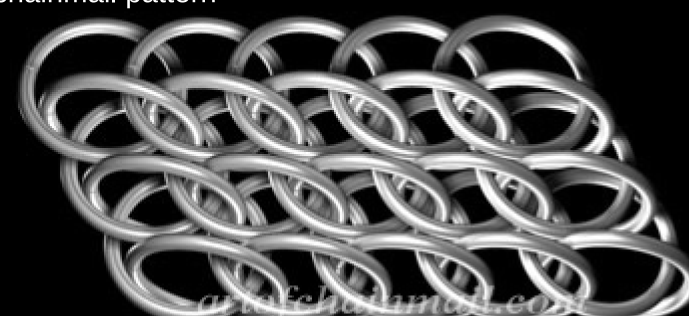


8 in 2 “King mail” pattern



6 in 1 chainmail pattern

Japanese pattern, etc.



1 in 6 “Persian” pattern

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iRings

From idea to prototype

V4 – 5” diameter wheel in stainless steel chainmail and delrin (November 2009)

iRings

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V4 – 5” diameter wheel in stainless steel chainmail and delrin (November 2009)

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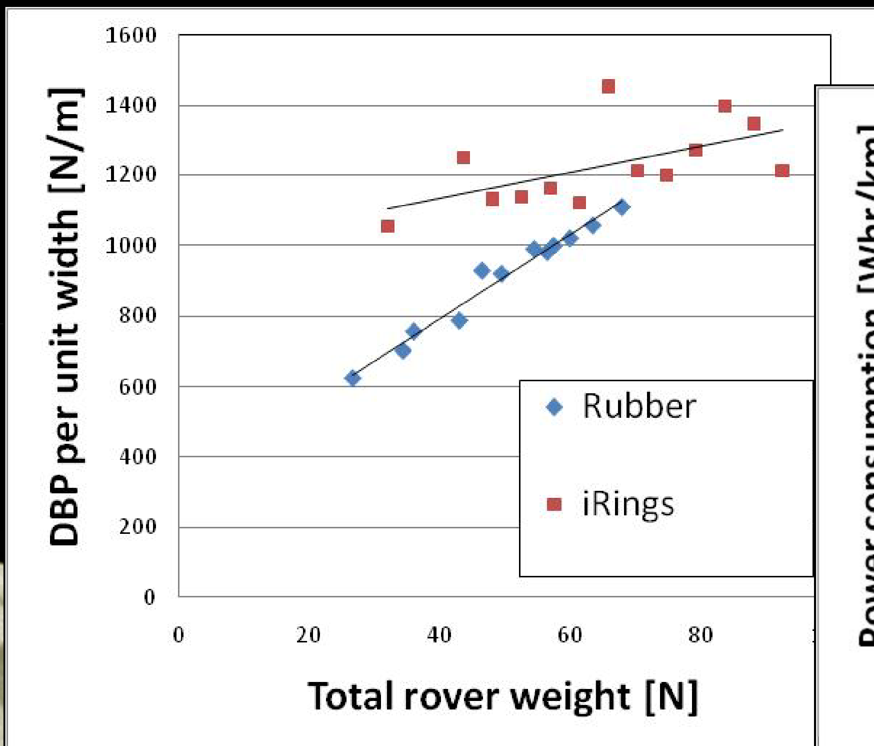

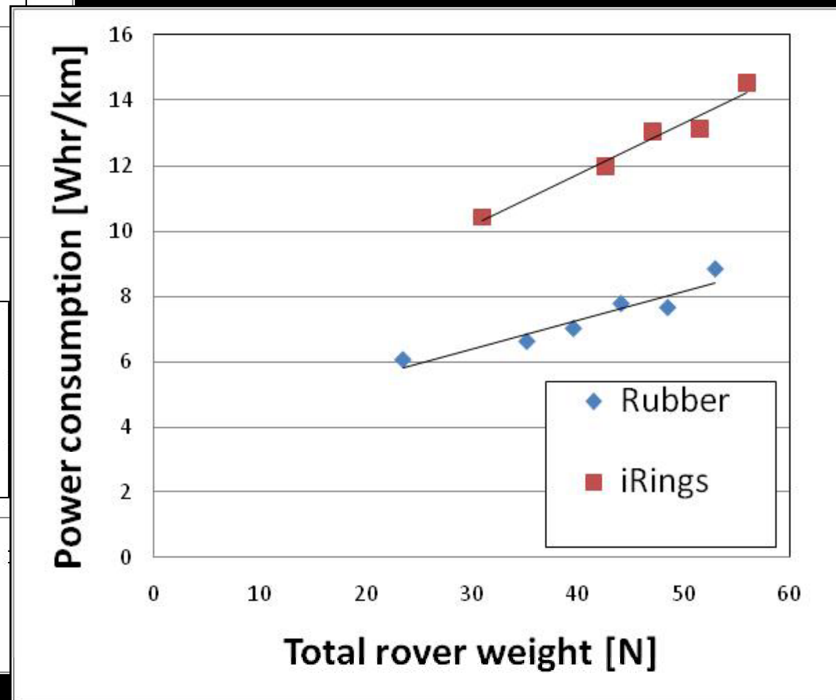

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iRings

From idea to prototype (future activities)

V5 – 8” diameter wheel in stainless steel chainmail and 3/8” media

V6 – 22” diameter wheel in stainless steel chainmail and 1” media

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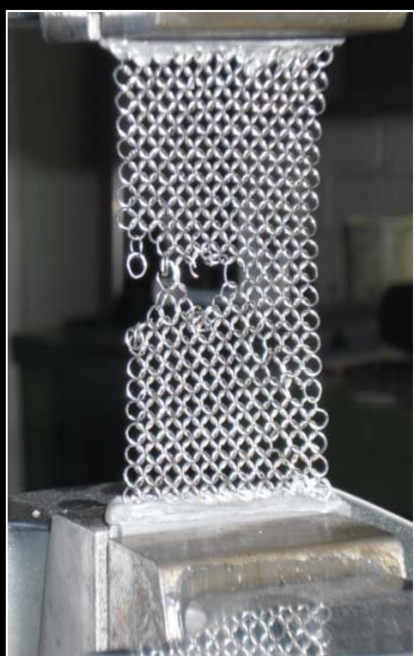
Summary

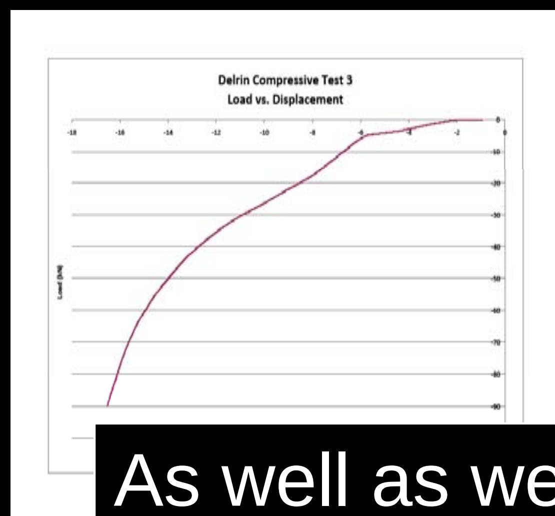
Heavier → contribute to rover stability
Traction → comparable to rubber
Compliance → conforms to rock surfaces
Shock absorption during mobility
Potential to link with an elastically compliant rim
Stand-alone, link to other space technologies or a transition from one to the other

& possible interactions…

Designed to meet a particular operational life

- Particulate filler → Delrin, PEEK with glass for higher abrasive resistance.





As well as wear modelling, simulation and validation

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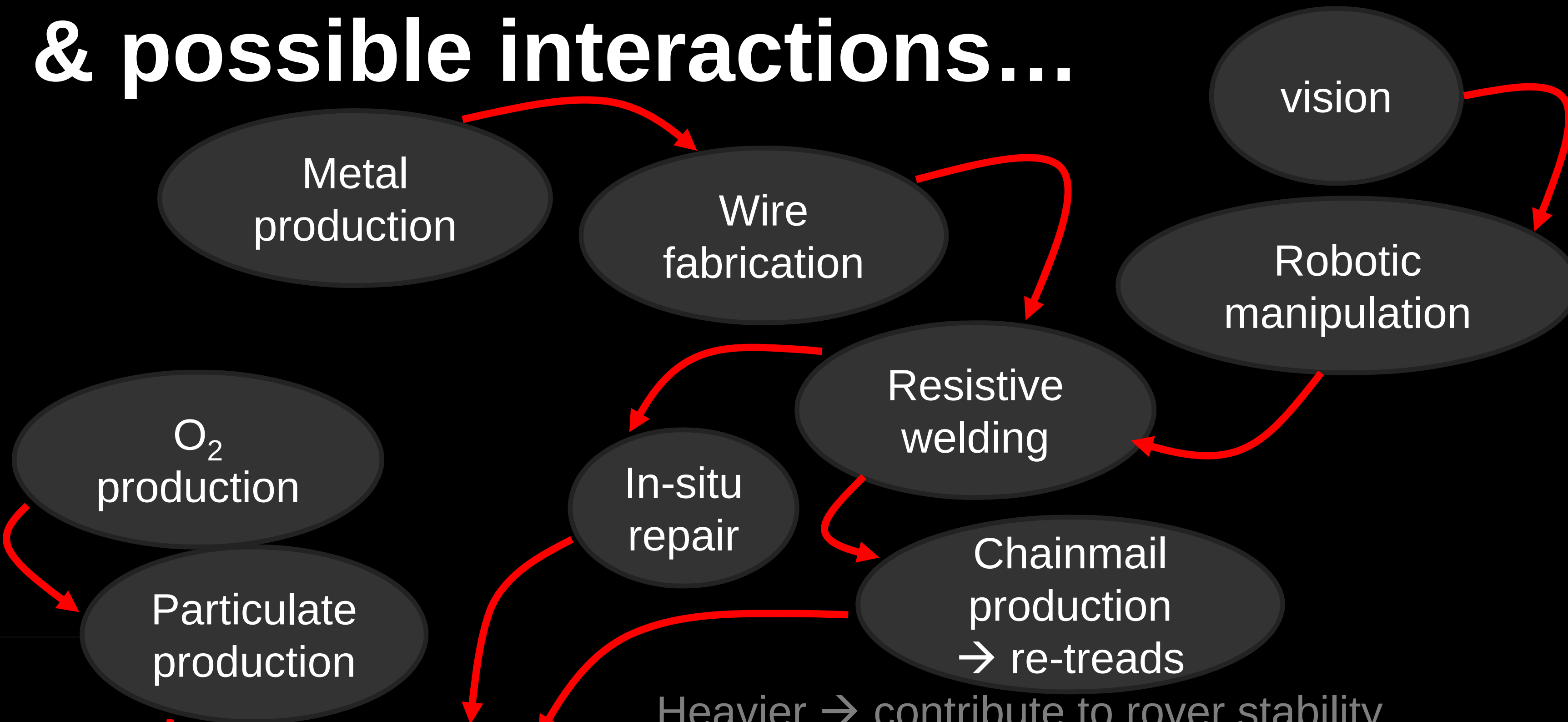
& possible interactions…



- Heavier → contribute to rover stability
- Traction → comparable to rubber
- Compliance → conforms to rock surfaces
- Shock absorption during mobility
- Potential to link with an elastically compliant rim
- Stand-alone, **link to other space technologies** or a transition from one to the other

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& possible interactions…

Heavier → contribute to rover stability
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Conclusions

a) Physical facilities are typical of what one would need in the investigation of lunar wheel development.

b) Virtual facilities include DEM modelling of ground/wheel interaction, wear and dust mitigation, multi-disciplinary design optimization, powertrain modelling as a function of terrain topology and multi-physics modelling of electric motor performance.

c) In terms of wheel concepts, the wheel design space is being explored and future activities will undoubtedly explore other potential wheel structures.

d) a new “class” of particulate filled wheels has been defined and one possible manifestation is dubbed “iRings”.

e) Initial results on a reduced scale 5” diameter “iRings” wheel indicate that wheel traction is increased at the cost of increased power consumption while presenting energy dissipating and compliant characteristics.

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