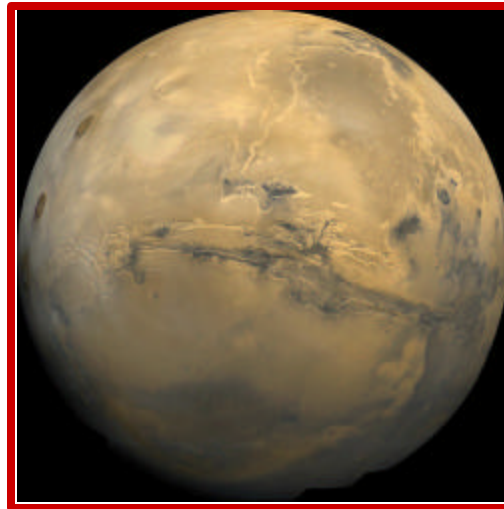
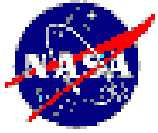


ANALYSIS AND DESIGN OF A SMALL ROBOT FOR MARTIAN REGOLITH EXCAVATION



Tim Muff, R. H. King, and M. B. Duke



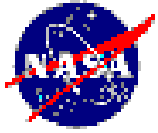
Excavation System Objectives



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- Develop a system that can effectively remove, transport and process the Martian regolith.
- Develop an excavator concept capable of working in a Martian environment.
- Develop an excavation plan to efficiently remove the Martian regolith.
- Model and simulate excavator in operation.
- Build and test an excavator prototype.
- Validate models used in design process.

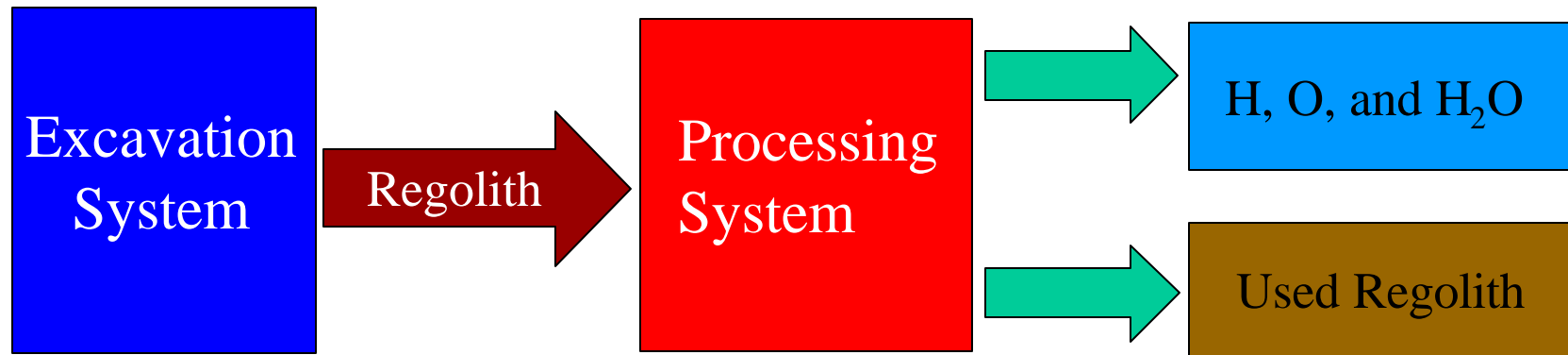


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Project Subsystems



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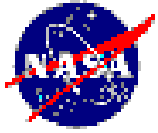


Excavation System

- Collects, sorts, and delivers regolith to processing plant.

Processing System

- Heats collected regolith to drive off volatiles.
- Extracts H, O, from volatiles and stores H₂O.



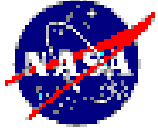
Earth-based Technologies



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- Choose a system based on proven terrestrial mining technologies.
- Objective requires a simple, productive, and highly reliable system.
- Capable of being scaled down in size without affecting productivity
- Capable of working in reduced gravity environment of Mars
~ 1/3 g.



Earth-based Technologies



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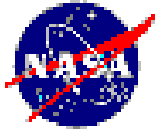
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Terrestrial Mining Systems:

- Front-end Loader
- Dragline
- Slusher
- Hydraulic Shovel
- Bucket-wheel Excavator

Selection Criteria:

- Simplicity
- Productivity
- Reliability



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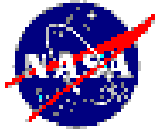
Design Base



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Bucket-wheel Excavator

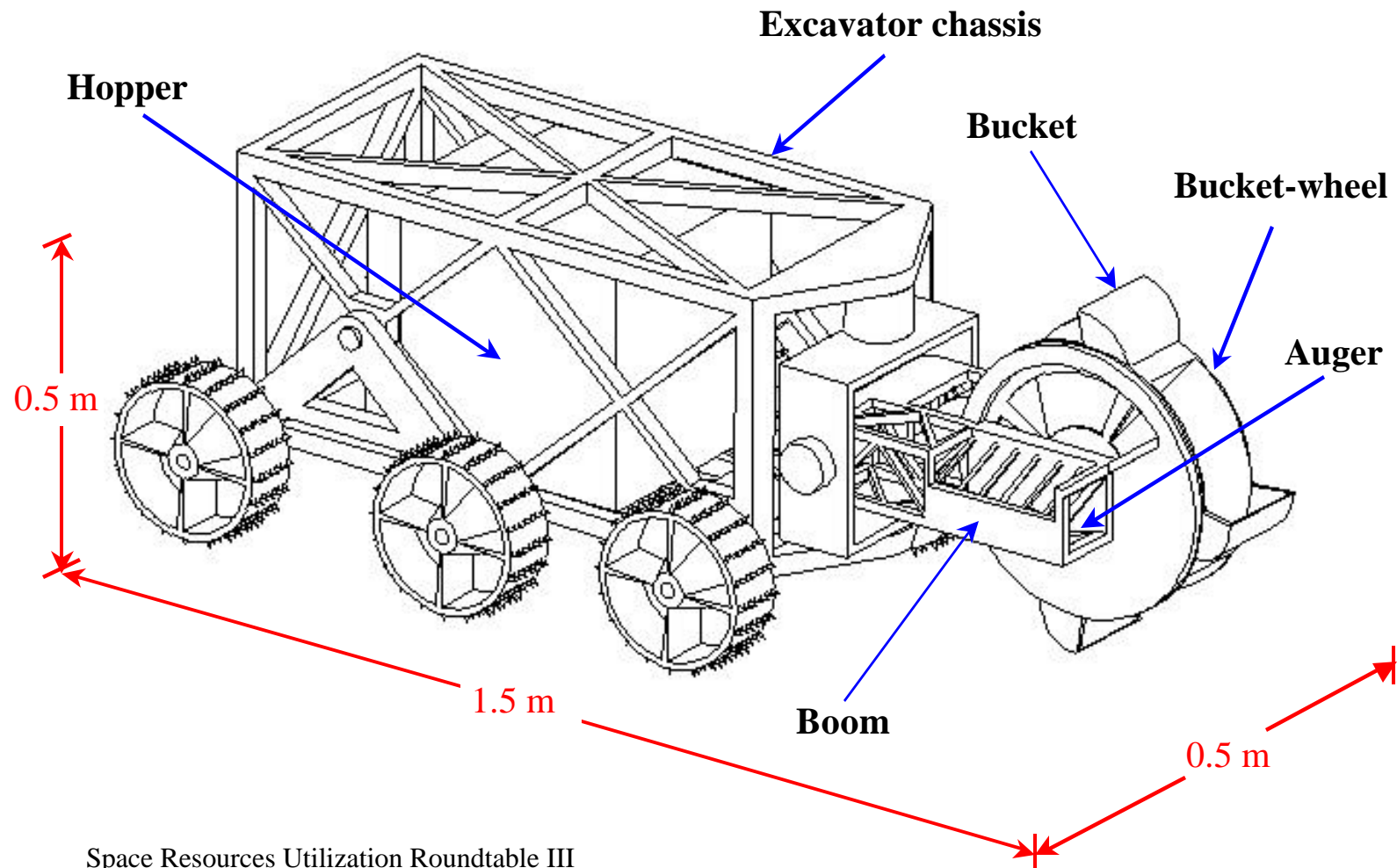


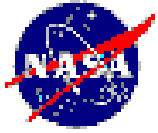
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Concept Design



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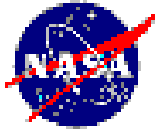
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Excavator Modeling



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- Characterize excavator motion during operation.
- Predict forces required to remove material.
- Predict reaction forces generated within excavator while in operation.
- Estimate power requirements of system.
- Use results from modeling process to size motors and other structural components.

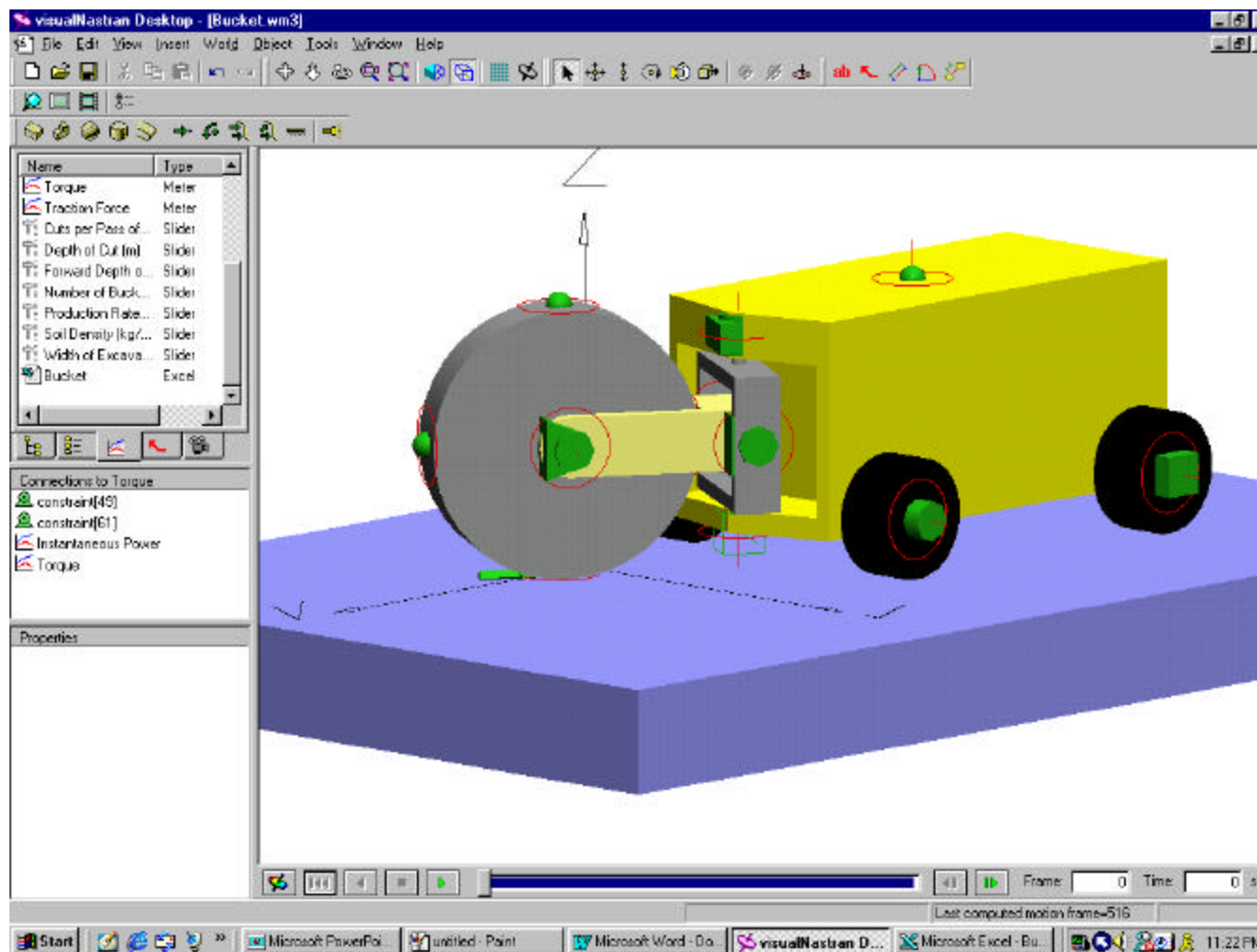


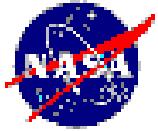
Excavator Modeling



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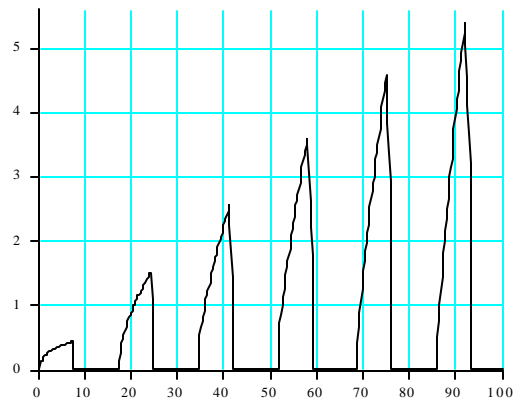
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Excavator Modeling



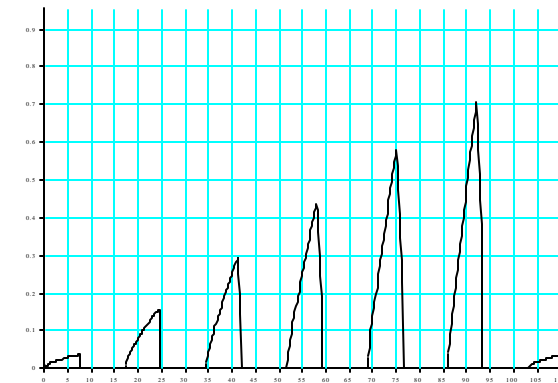
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Cutting Wheel (Nm) vs. time (s)

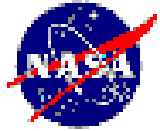


Torque on
bucket-wheel

Instantaneous Power (W) vs. time (s)



Instantaneous
Power



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Bucket-wheel Optimization



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- Bucket-wheel design affects excavation forces and power consumption.

- Design Variables:

Bucket-wheel diameter

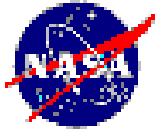
Width of excavator

Number of buckets

Depth of cut

Width of buckets

- Incorporated excavator model with commercial optimization package VisualDOC.

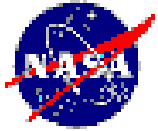


Prototype Design

- Width of bucket = 0.10 m
- Bucket-wheel dia. = 0.50 m
- Number of buckets = 4
- Excavator width = 0.50 m
- Depth of cut = 0.05 m

Optimized Design

- Width of bucket = 0.05 m
- Bucket-wheel dia. = 0.30 m
- Number of buckets = 12
- Excavator width = 0.58 m
- Depth of cut = 0.05 m



Bucket-wheel Optimization

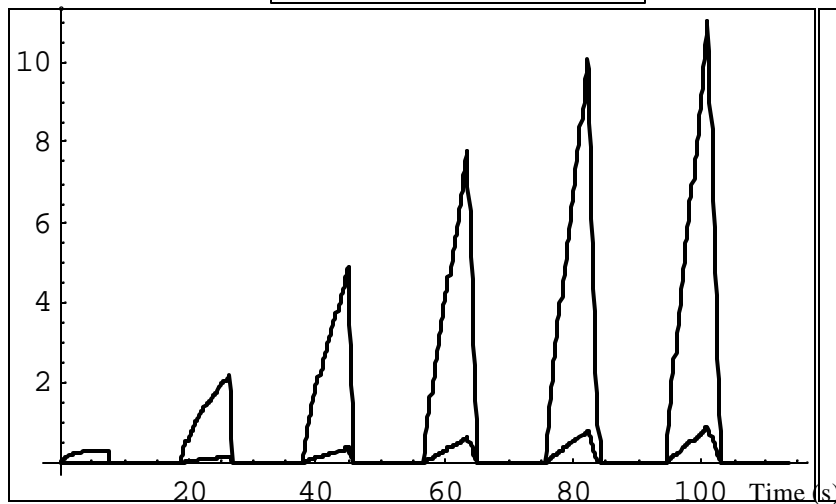


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- Results from initial optimization show a decrease in excavation reaction forces and power.

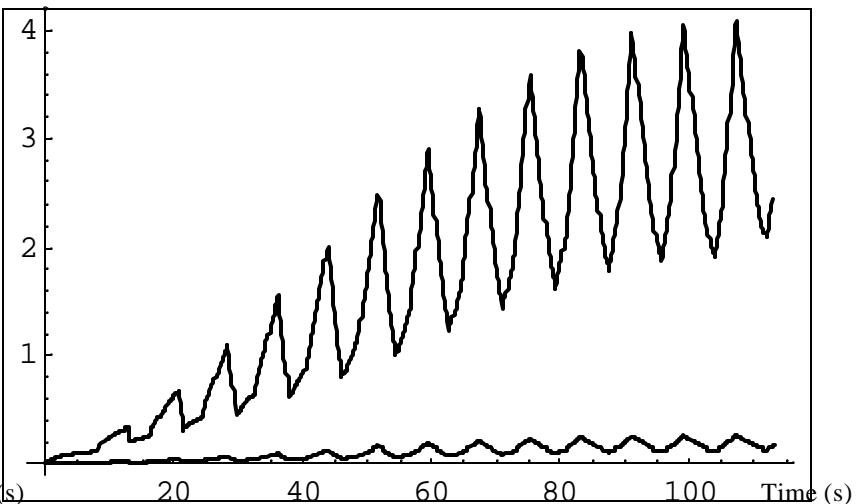
Concept Design



Torque (N-m)

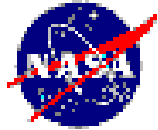
Power (W)

Prototype Design



Torque (N-m)

Power (W)

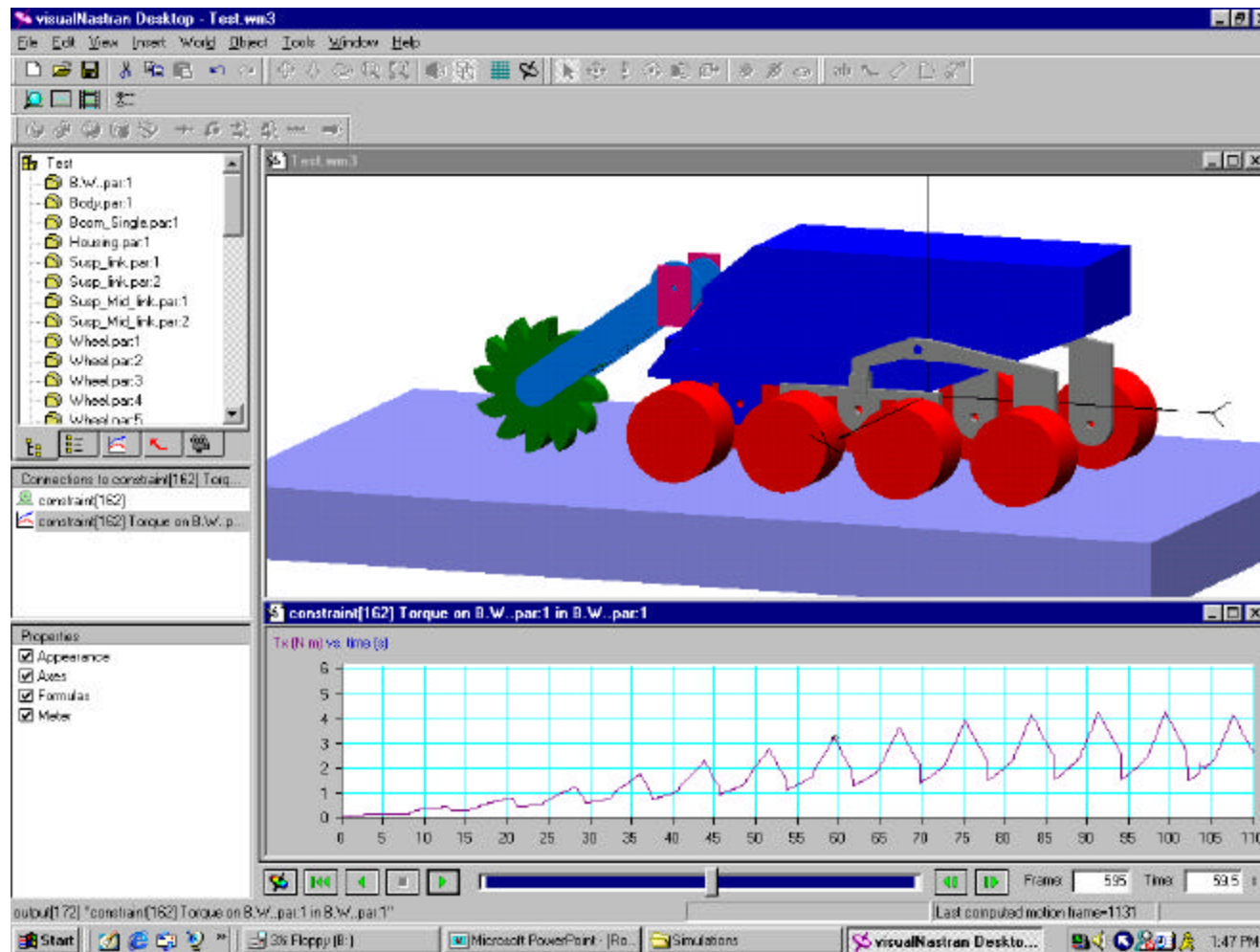


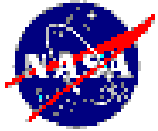
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Prototype Modeling



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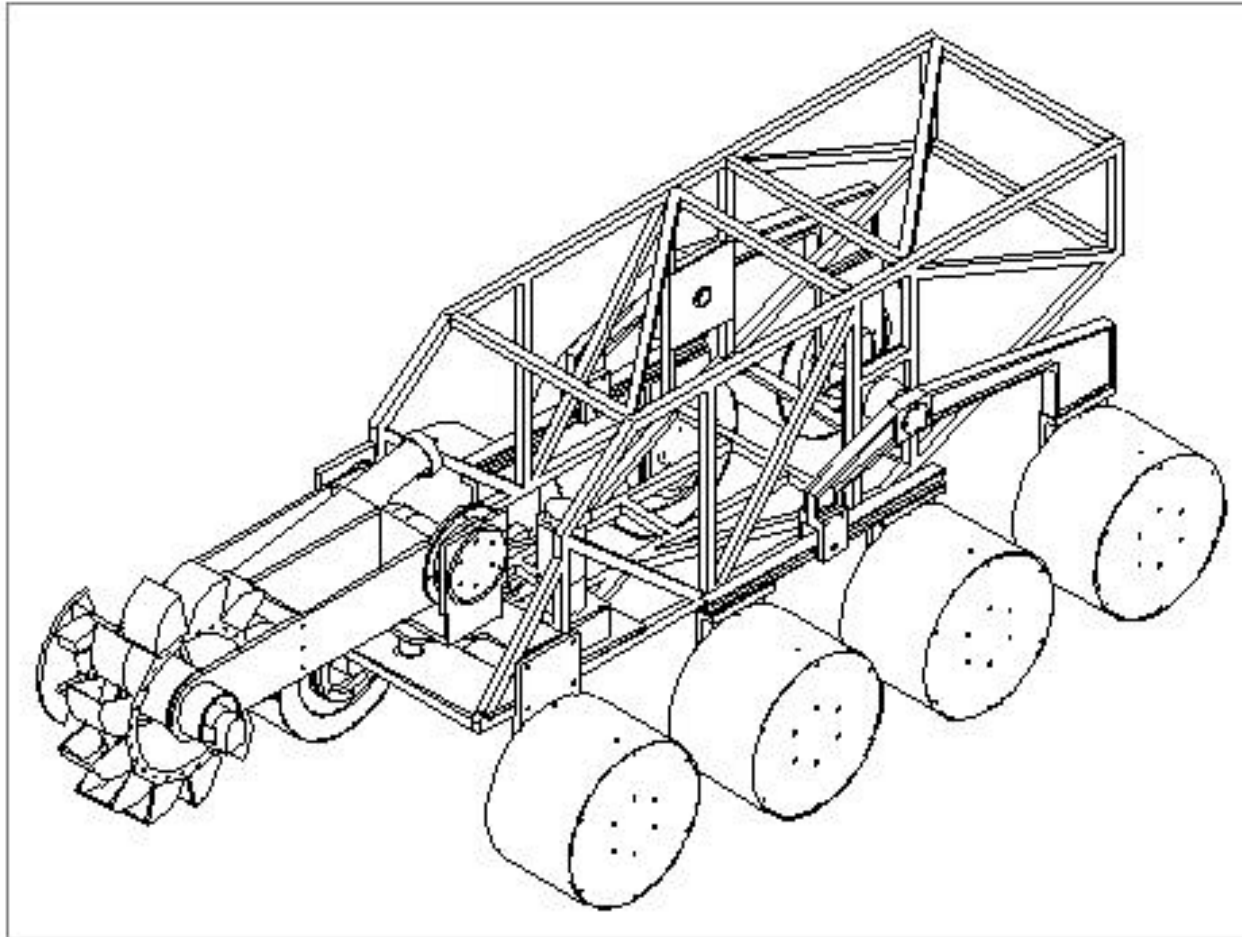


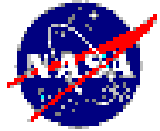
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Prototype Design



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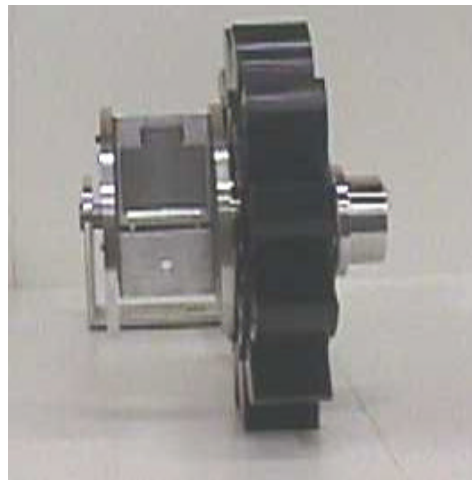
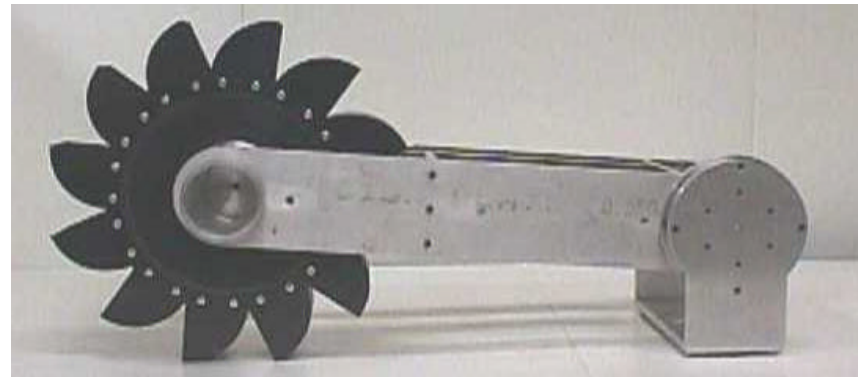
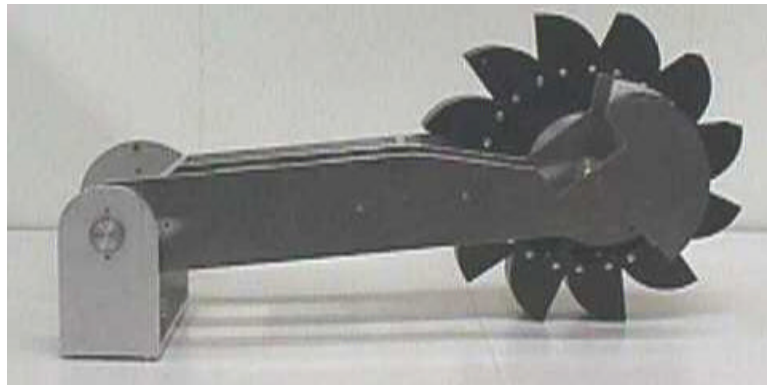
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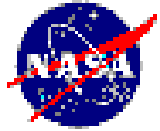
Prototype Construction



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Bucket-wheel and boom





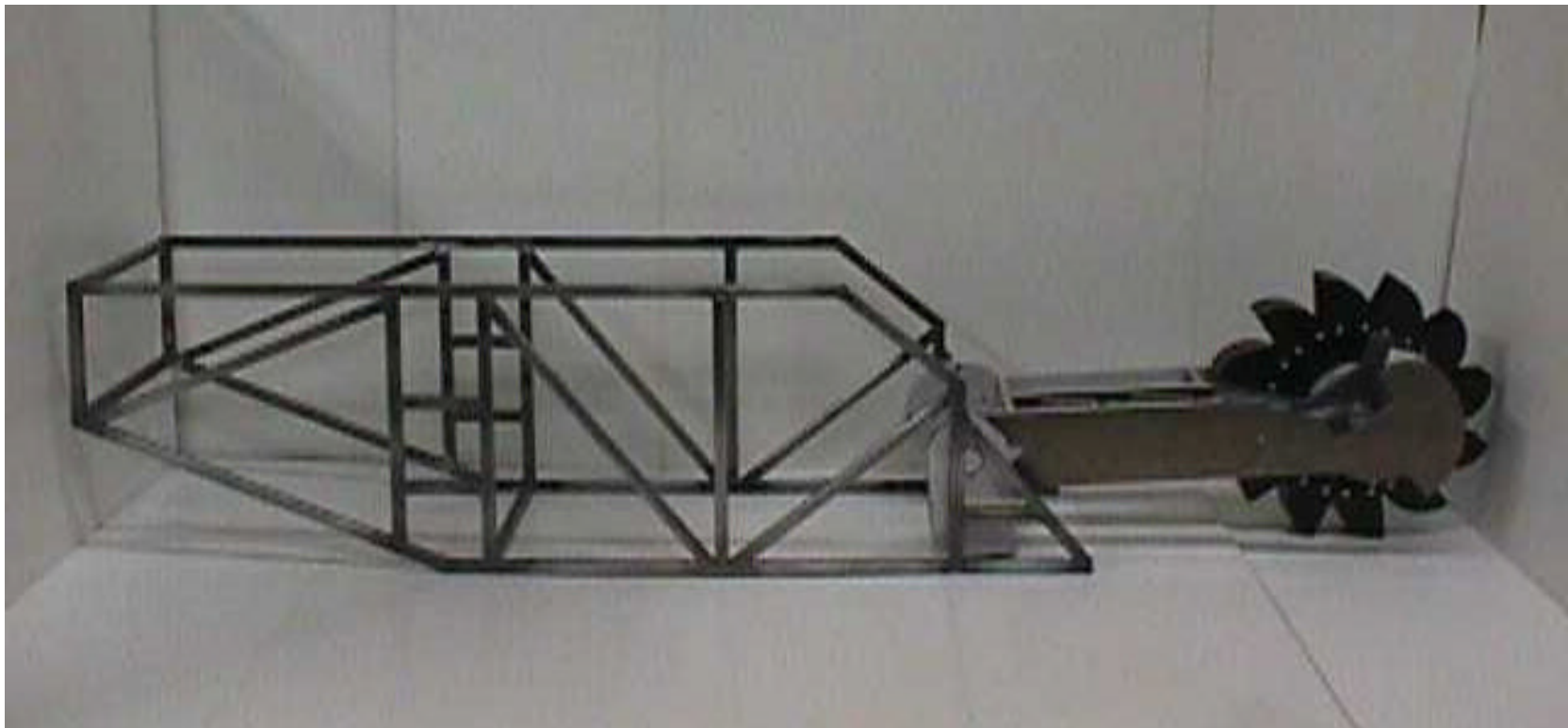
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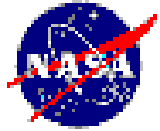
Prototype Construction

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Excavator Chassis and bucket-wheel





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Testing and Validation



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- Collect data from prototype excavator while actually removing material.
- Validate models used to predict excavation forces, power consumption, etc.
- Test excavator operation in simulated Martian environment.
- Demonstrate effectiveness of excavator design.