Jacking and Equalizing Cylinders for NASA- Crawler Transporter

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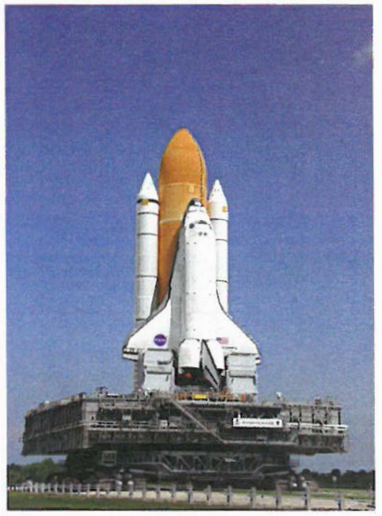
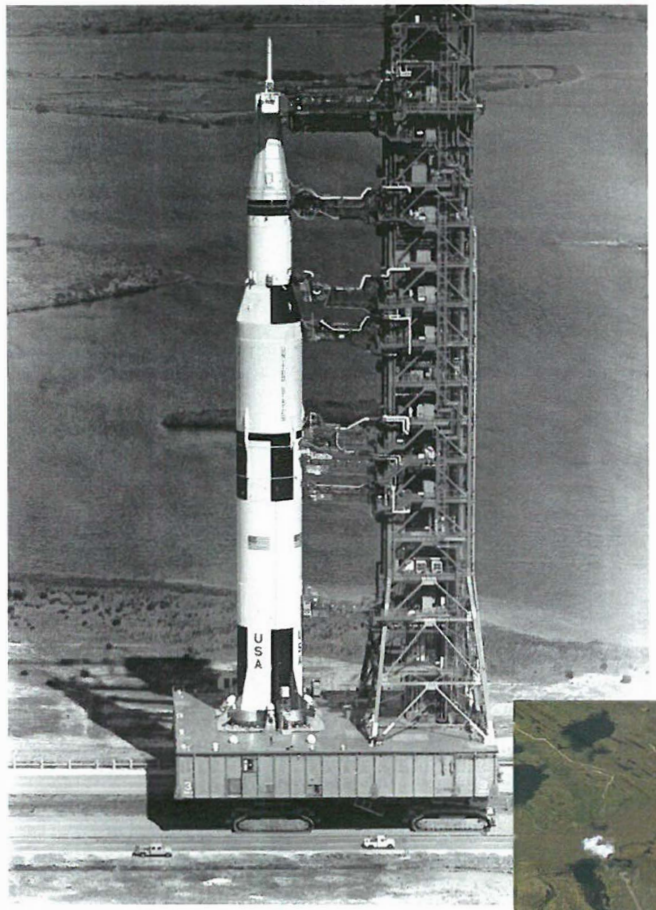


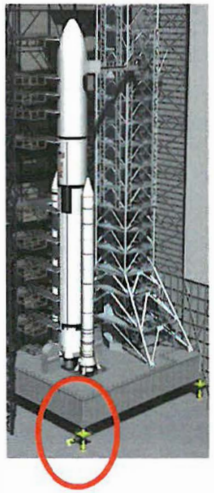
Crawler History

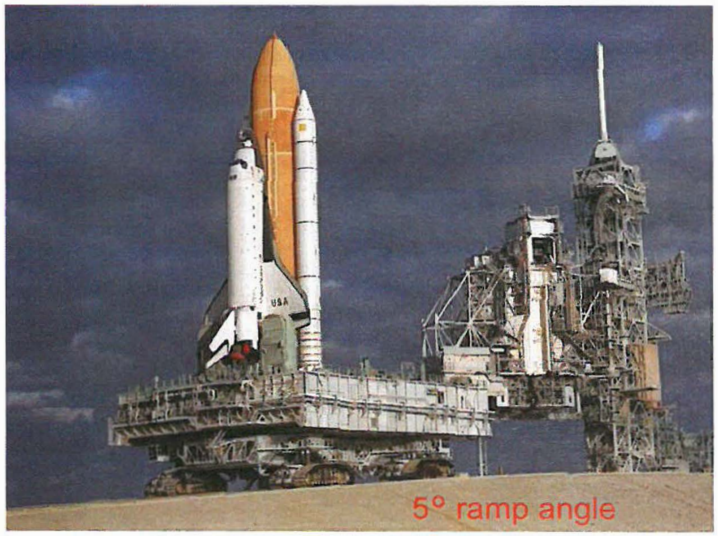


- two crawler transporter at Kennedy Space Center (KSC) were built in 1963 – 1965
- designed to transport a the Saturn V rocket with Apollo spacecraft and launch platform
- crawler data: 40 m length, 35 m width and a maximum load capacity of 6.000 ton
- 5,6 and 6,8 km long crawler way from the assembly building to the two main launch pads
- later the crawler transporters were used for Spacelab, Apollo, Apollo-Soyuz and all Space Shuttle missions

Functions of the JEL- System

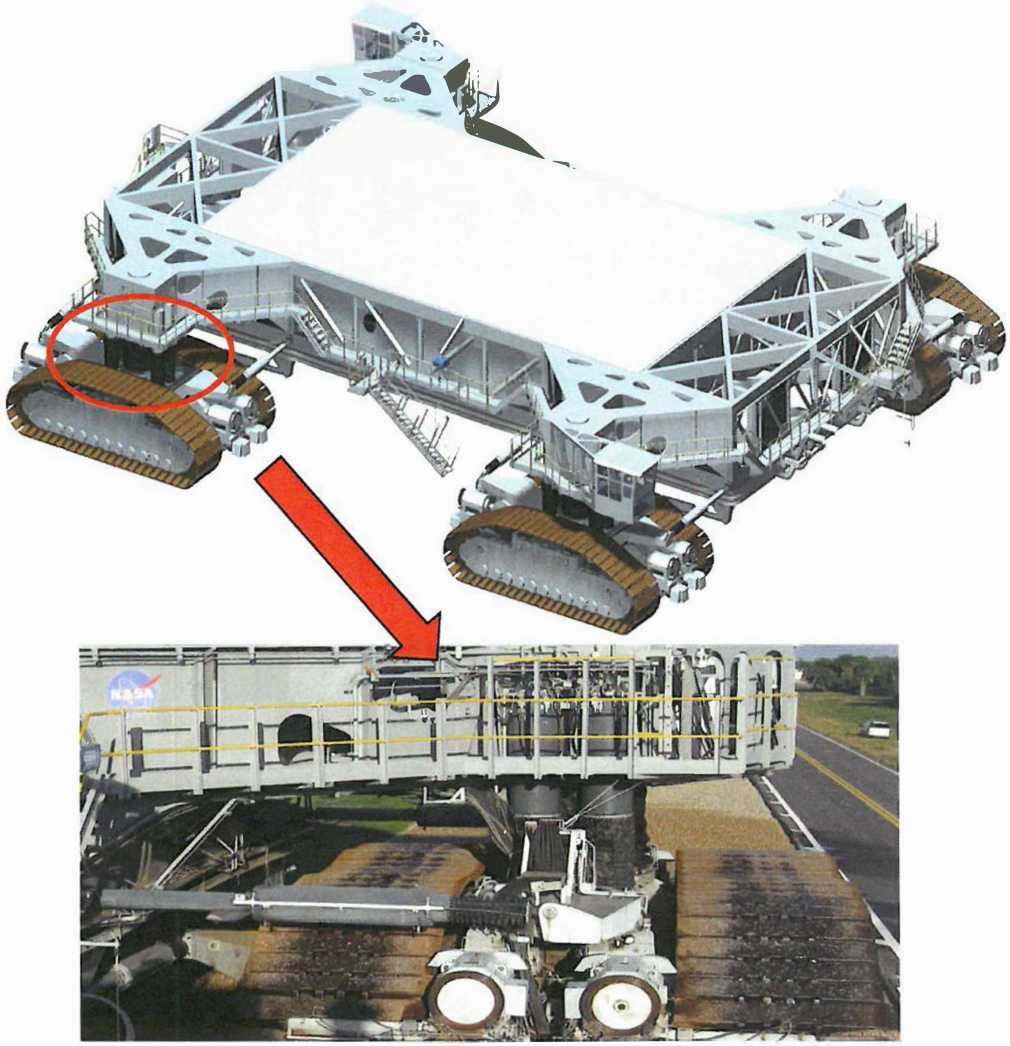
1. Jacking and drop off of the launch platform to the stationary columns
2. Equalizing the launch pad and the rocket during transport
3. Levelling the launch platform and the rocket during launch pad ramp ride





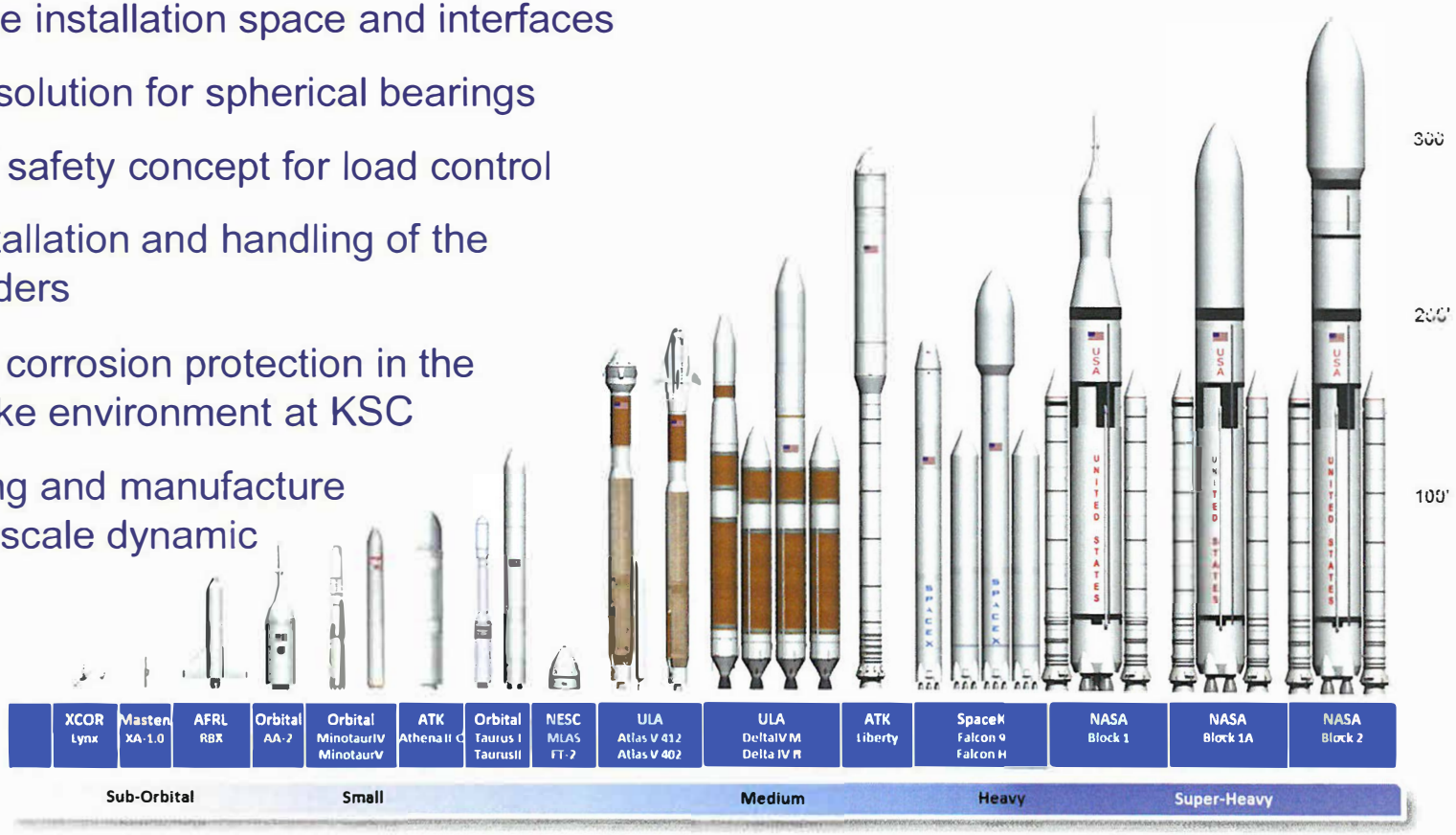
Working Principle of the JEL- System

- 16 pieces of JEL- cylinders in total
- 4 pieces of single acting cylinders in each under-carriage, arranged around a center pin
- maximum stroke length of 2.000 mm allows ramp angles of maximum 7°
- all four cylinders are hydraulically synchronized
- mechanical interfaces were done with spherical bearings, steel – steel type
- steering angle in bends will tilt and twist the cylinders

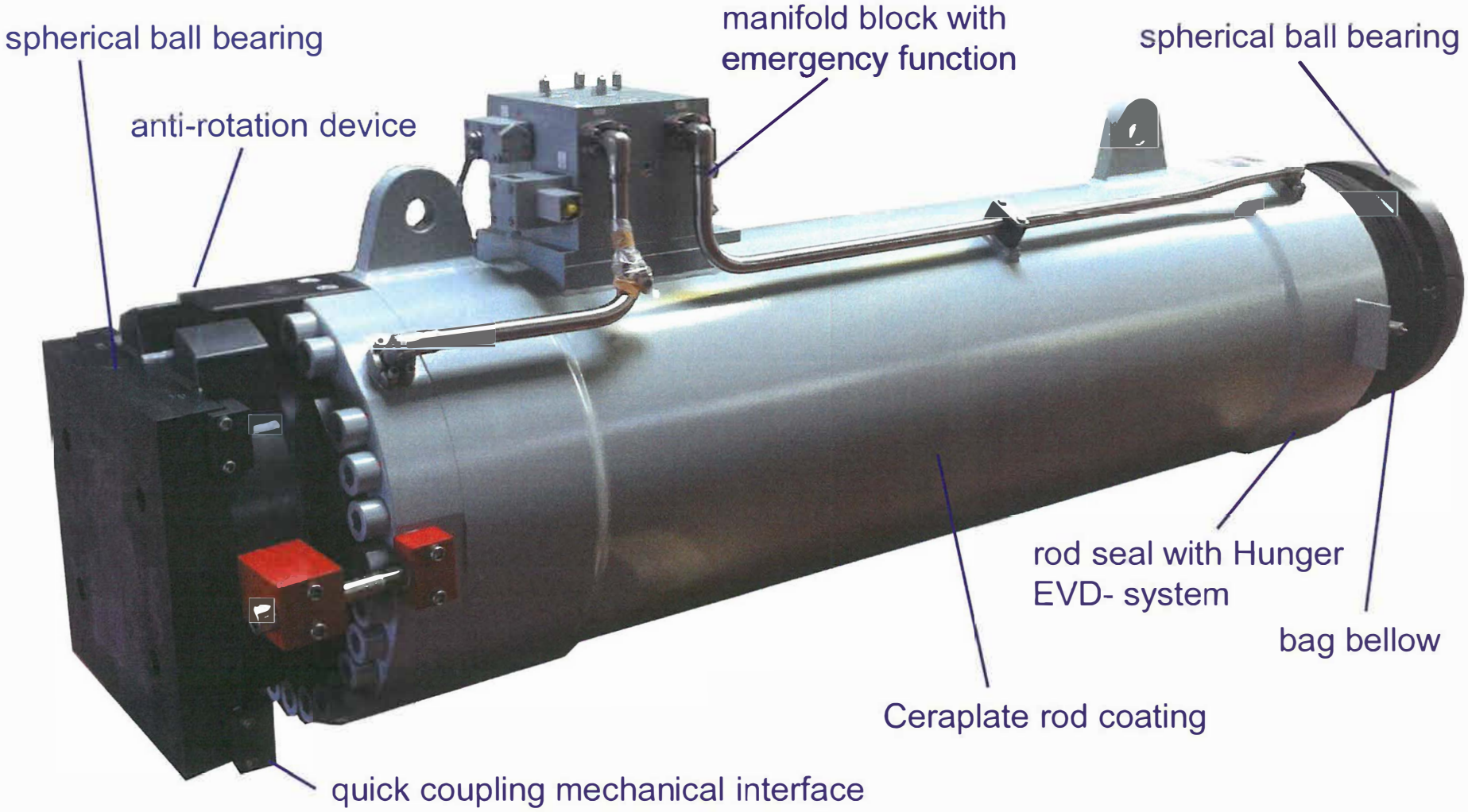


Main Requirements for the new JEL- System

- load capacity to be increased by +50% for super-heavy rocket and space craft generation
- using same installation space and interfaces
- improved solution for spherical bearings
- multi level safety concept for load control
- easier installation and handling of the JEL- cylinders
- enhanced corrosion protection in the offshore-like environment at KSC
- engineering and manufacture of a 1 : 1- scale dynamic test rig

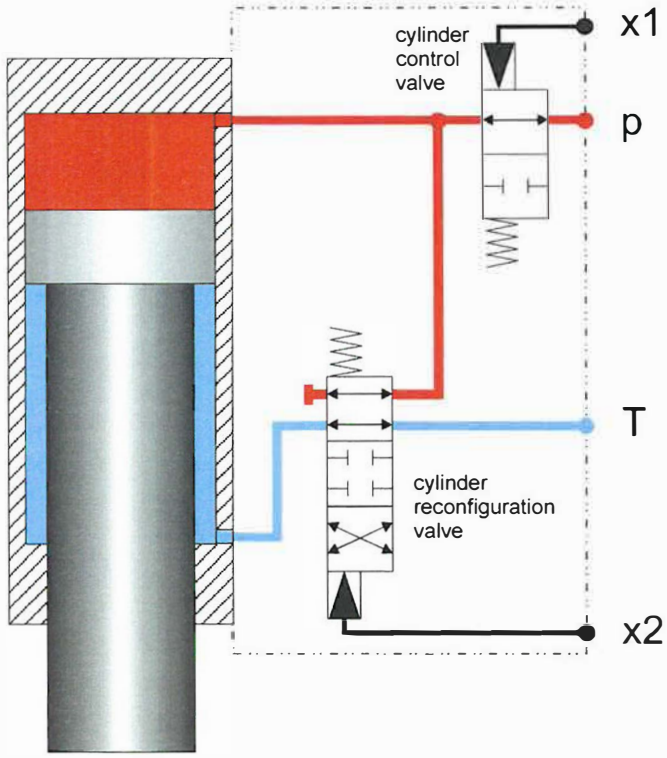


Cylinder Main Features



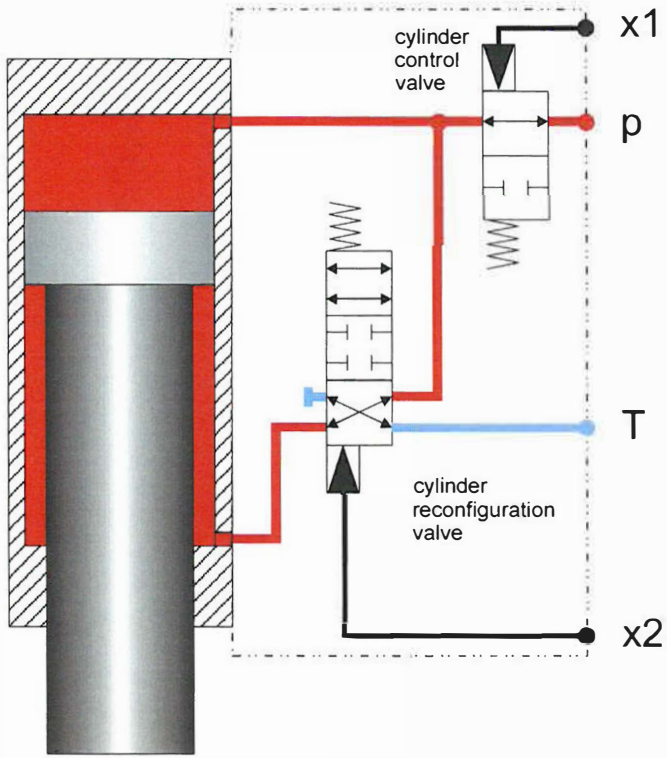
Normal Operation Mode

- piston seal is the active seal
- normal operation pressure



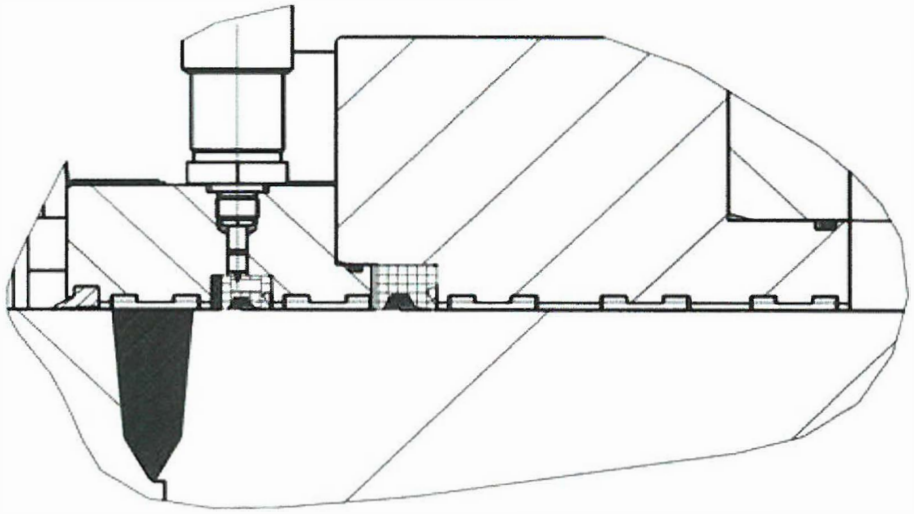
Emergency Operation Mode I

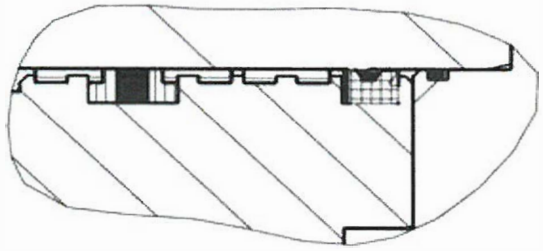
- rod seal is the active seal
- cylinder still maintains 77% of the load



Seal and Guiding System

- plastic compound guiding elements with the possibility of high side loads
- TDA and GD1000K seal as main seal system
- 1x TDI seal and 1x externally adjustable seal (EVD) for **Emergency Operation Mode II**
- standard wiper element

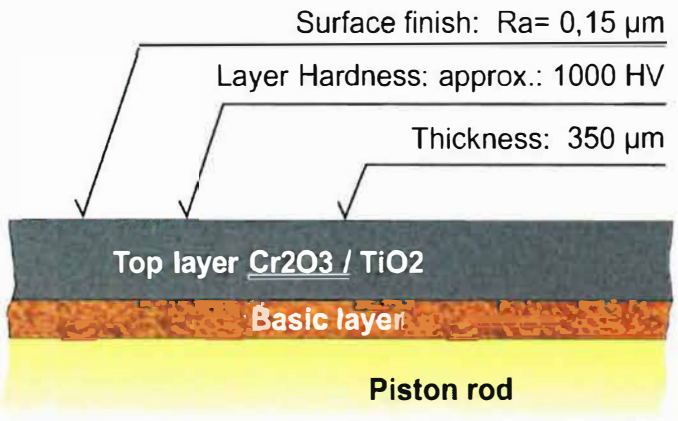




Ceraplate Ciston Rod Coating

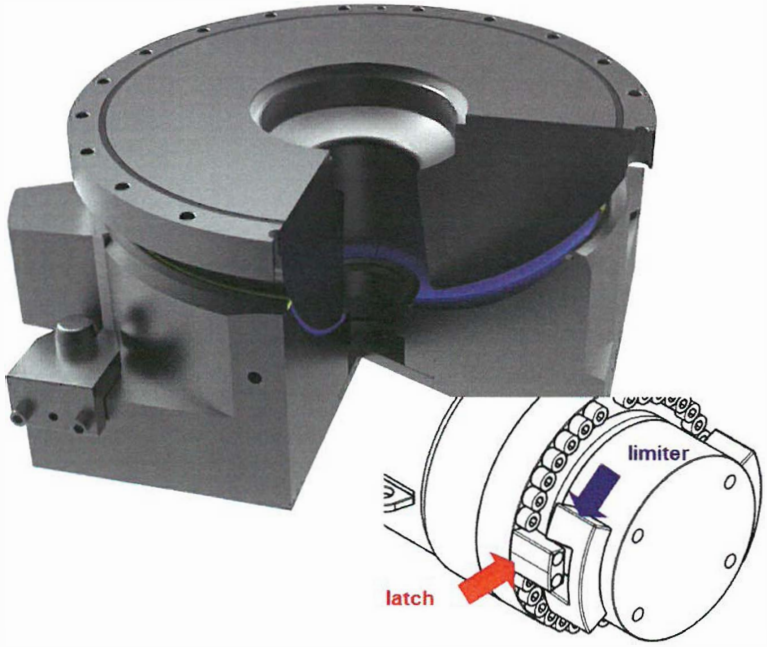
- thermal sprayed metal oxide coating Ceraplate for corrosion protection in offshore-like atmosphere
- coating hardness and ductility allows high side loads

Ceraplate - layers



Spherical Ball Bearings

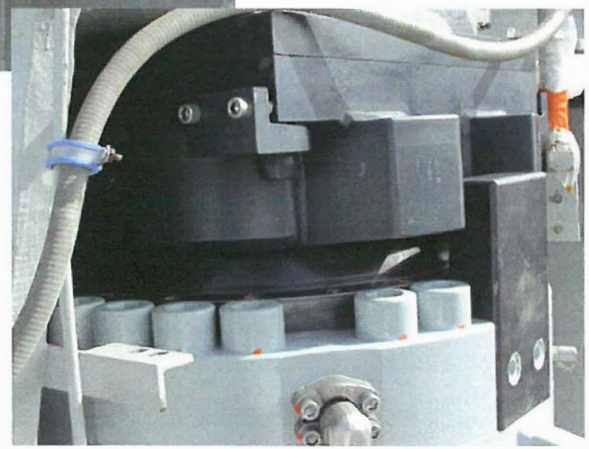
- old bearing elements were already overloaded and did show some cracks
- old design was not maintenance free



- new bearing elements are designed for the increased load
- 7° tilting angle in any direction
- maintenance free H-Glide bearing material with maximum compressive strength of σ_D= 160 MPa
- integrated anti-rotation device

Handling and Installation

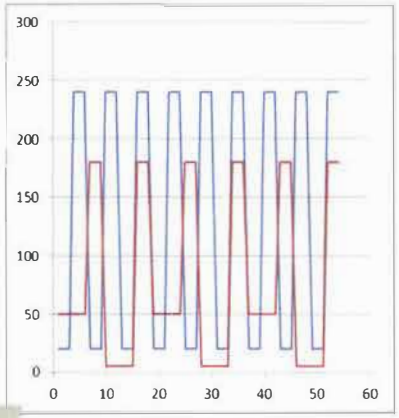
- new mounting interface with adaptor plate and quick coupling system
- wedge system allows mounting without heavy tooling

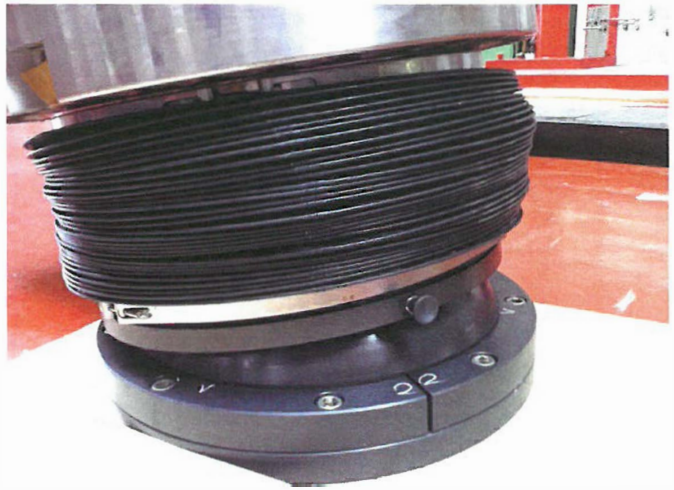


- lifting and handling fixture designed for easy installation of the JEL- cylinders

Static Test Arrangement

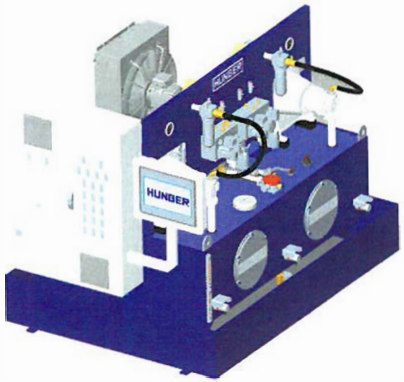
- pressure test in extended and retracted position
- load frame for full testing load in mid-stroke position
- load cycles on different pressure levels
- functional test of manifold block in normal and emergency operation mode
- test of tilting angle of the spherical ball bearings

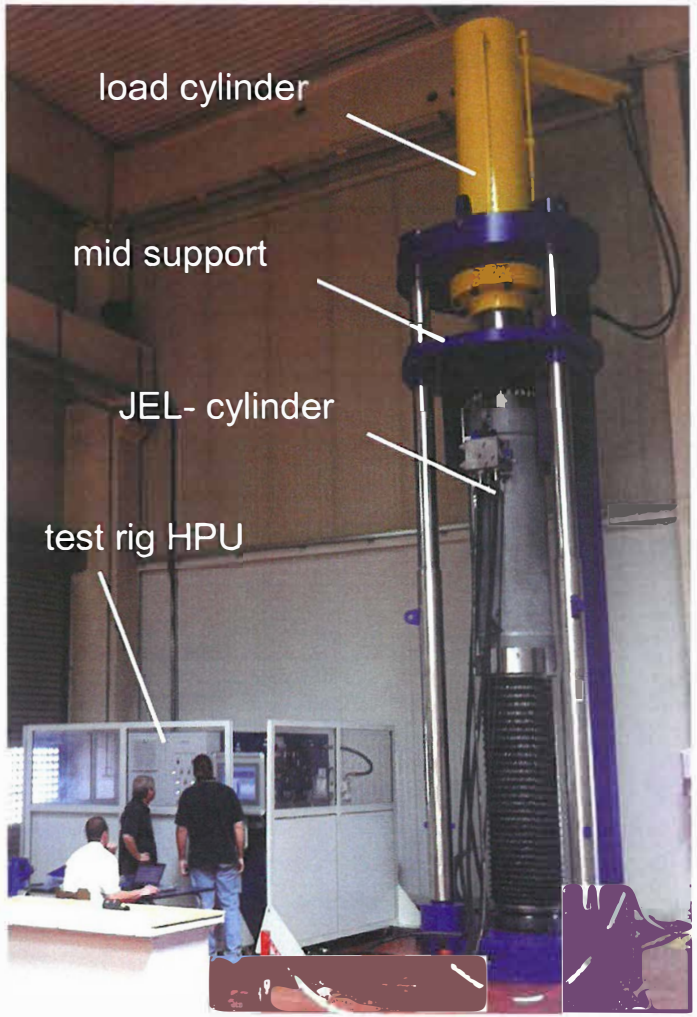




Dynamic Test Rig Design

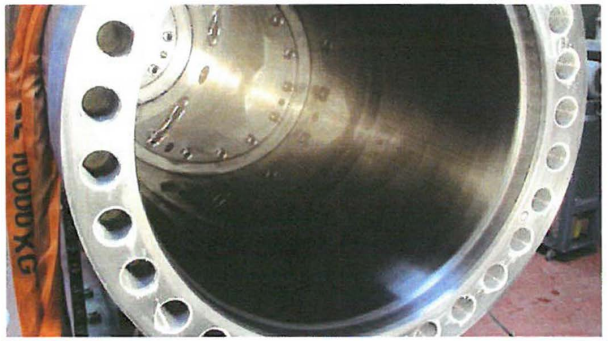
- test rig HPU with two independent controlled axis
- full load tests up to 7.000 kN
- free programmable moving profile for JEL- cylinder
- free programmable load profile for JEL- cylinder
- multi channel measuring and recording system
- installation situation like in the crawler transporter
- simulation of jacking and levelling operation
- test runs for normal and emergency mode operation

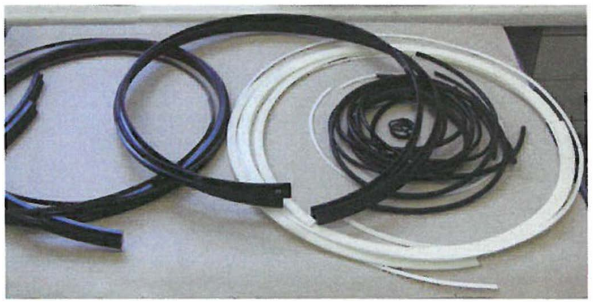


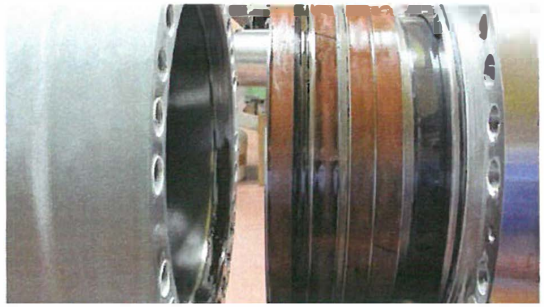


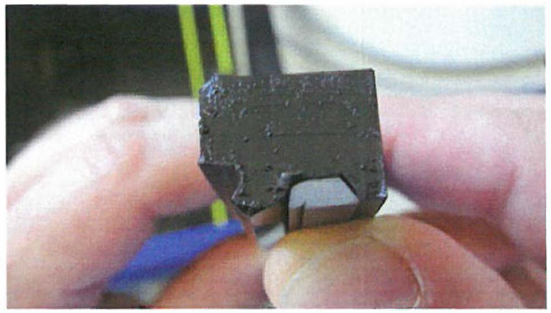
Investigation of JEL- Prototype-Cylinders after Testing

- complete dismantling of JEL- prototype cylinders
- investigation of all components regarding damages, defects or wear
- preparation of findings reports with performance, reliability and risk analysis
- presentation of results to NASA for final design approval and for type approval for manufacturing









Drive Test with two Prototype Cylinders

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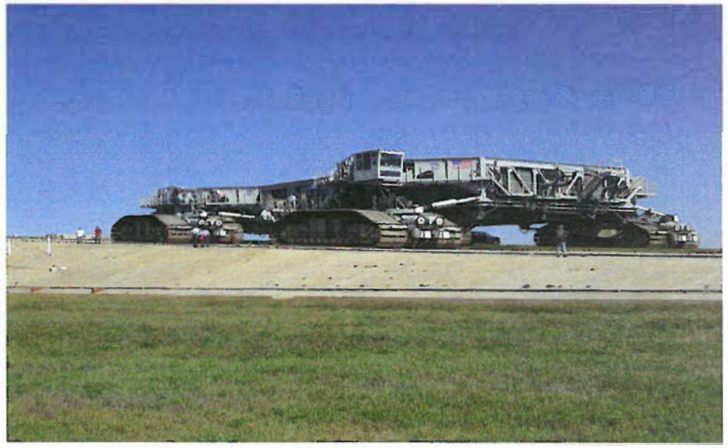
- two prototype JEL- cylinders together with two old JEL- cylinders in one under-carriage
- cornering ride with JEL- prototype cylinders
- ramp ride with JEL- prototype cylinders



➡ check of function and sealing

➡ check of collision free movement

➡ load holding tests

Conclusions

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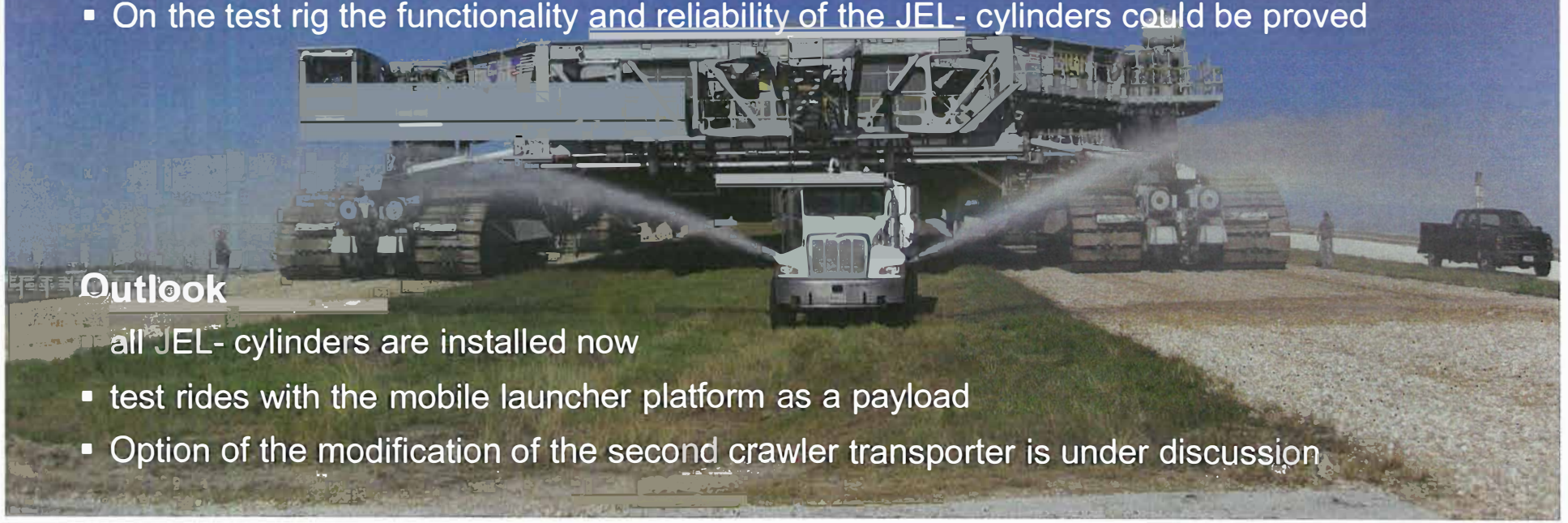
Summary

- load capacity could be increased by +50% with the new JEL- cylinders
- new JEL- cylinders fit into the existing installation space
- design for spherical bearings could be improved
- safety concept for load control was realized
- installation and handling of the JEL- cylinders could be improved
- On the test rig the functionality and reliability of the JEL- cylinders could be proved



Outlook

- all JEL- cylinders are installed now
- test rides with the mobile launcher platform as a payload
- Option of the modification of the second crawler transporter is under discussion