Sherpa in TransTerrA: SherpaTT

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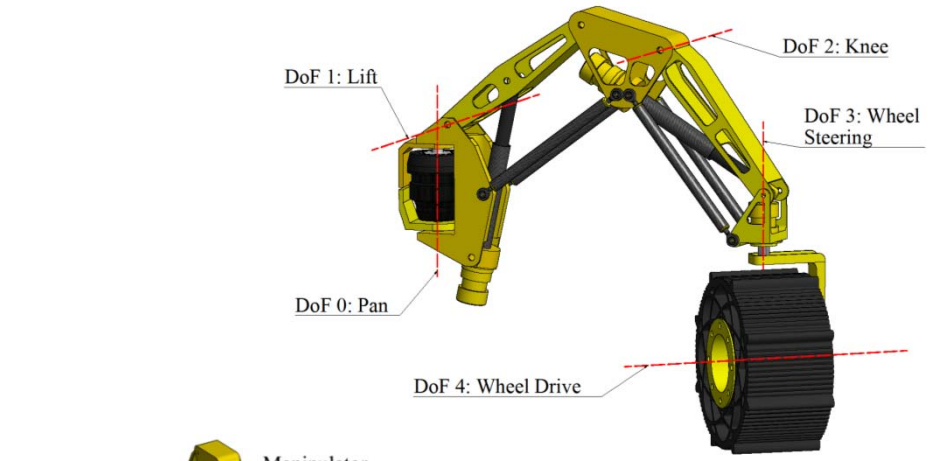
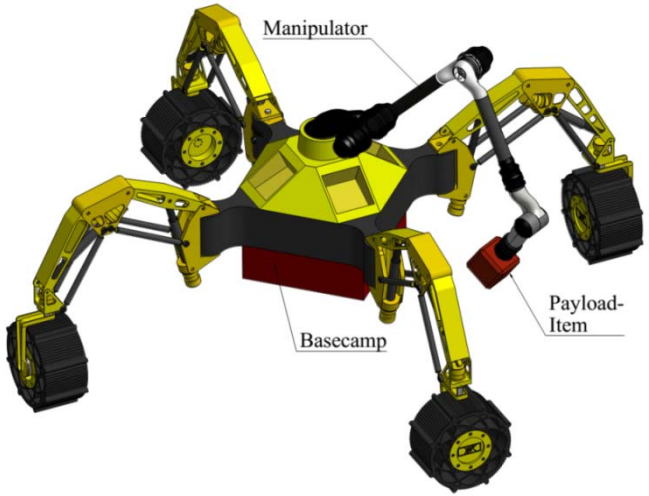
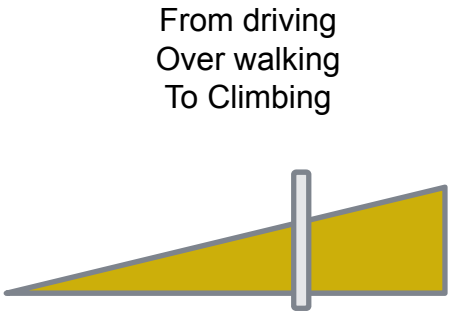




Why Active Suspension?

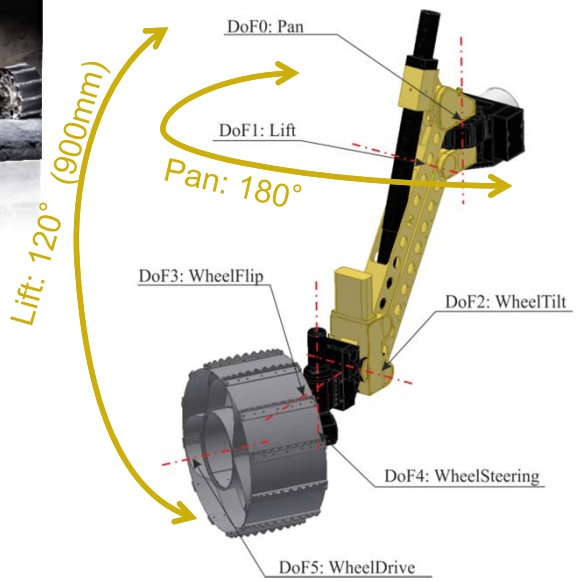
- Passive, most prominently Rocker-Bogie
  - Mechanics do the adaption, no control needed
  - Ground wheels have to give thrust needed to drive other wheels over obstacles
- Active: Control needed to be active
  - Thus: Higher computational efforts for (“low-level”) locomotion
- Active suspension provides higher locomotion capabilities in the long run
  - Free the system from stuck situations
  - Maneuverability: Obstacle size, non-continous path of wheels possible
  - Reconfiguration space from driving to walking
  - Combines benefits from rolling and walking behaviors

Karl-Heinz Laube / pixelio.de



Reiner Sturm / pixelio.de

Sherpa - Overview

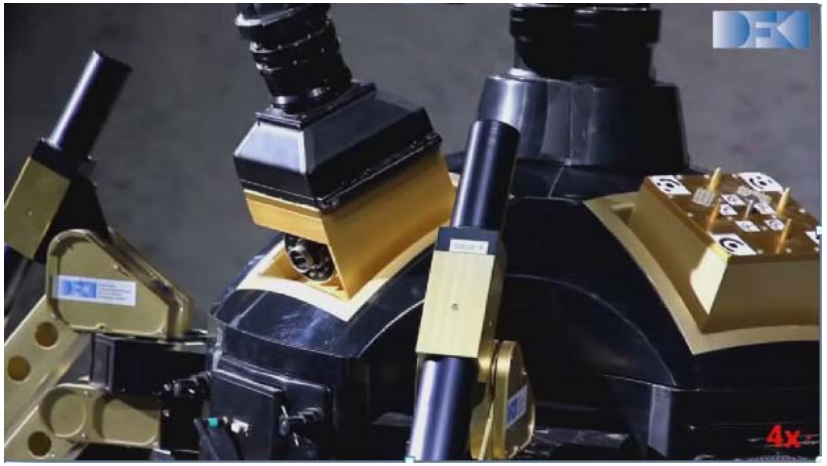


- Variable footprint
  - Track width: 660mm to 2610mm
  - Length: 2610mm to 660mm
  - Body height: -189mm to 711mm
- Mass: 160kg
- Max speed: ca. 500mm/s (HD 1:80)
- Torque per wheel: 59 Nm
- No. of active DoF: 6 per leg + 6 arm = 30 DoF
- Manipulator is strong enough to support the rover with two legs lifted
- Equipped with general purpose electro mechanical interfaces (EMI)
  - 4 passive/male around manipulator
  - 2 active/female (1x manipulator, 1x bottom of central body)

Video: Sherpa stepping over obstacle

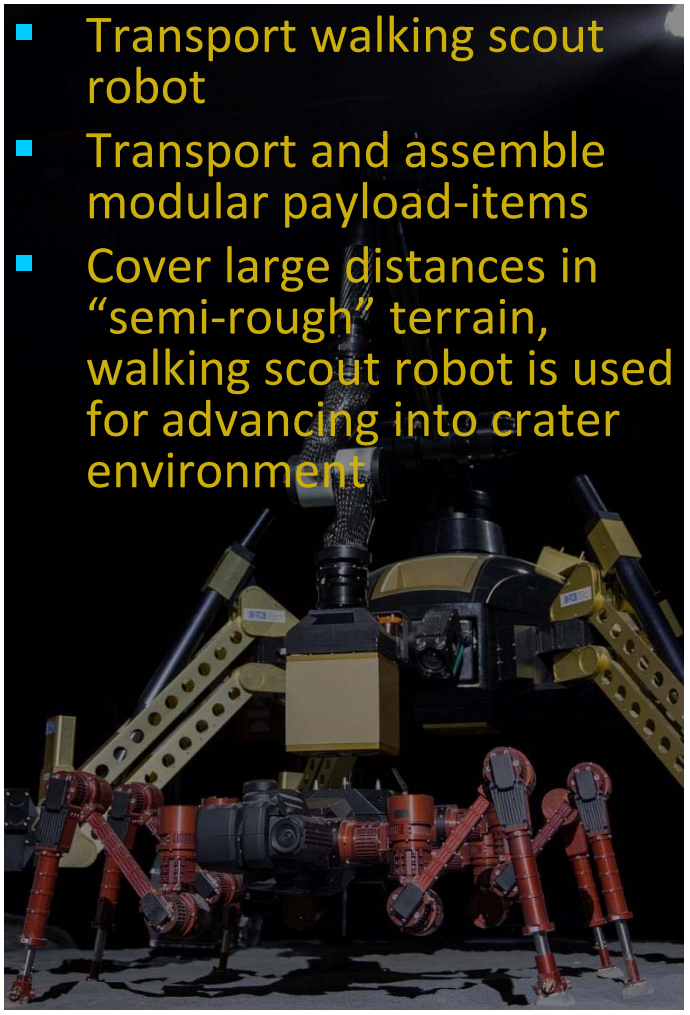
Role of Sherpa in MRS

Video: Sherpa lifting CREX with manipulator



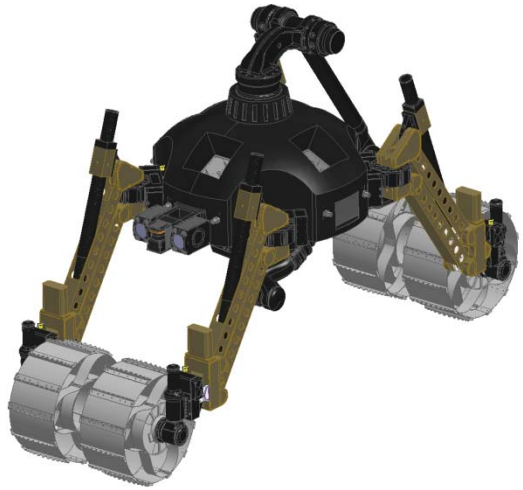
Video: Sherpa stacking Payload-Items

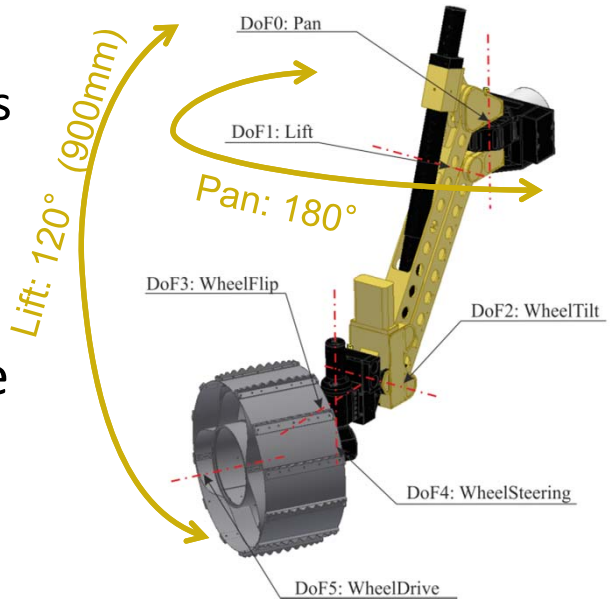
- Current design developed as part of a multi-robot system
  - Transport walking scout robot
  - Transport and assemble modular payload-items
  - Cover large distances in “semi-rough” terrain, walking scout robot is used for advancing into crater environment



Drawbacks Identified

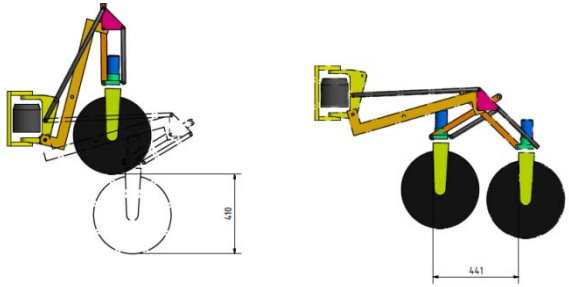
- Two joints Pan+Lift for placing the wheel in (x,y,z)
  - Underactuated/ Interdependency of DoF
- Tilt and Flip rarely used: Flexible wheels sufficient for small scale ground adaption
- High stow volume (compact pose not possible)
  - Approx. 2.25m x 0.8m x 1.35m =2.43m³
- Active Partner for docking to bottom interface needed
  - New scenario requires pick-up of passive payloads with bottom interface
- Missing F/T-sensor for sophisticated ground adaption
- Multiple different actuators increase maintenance efforts

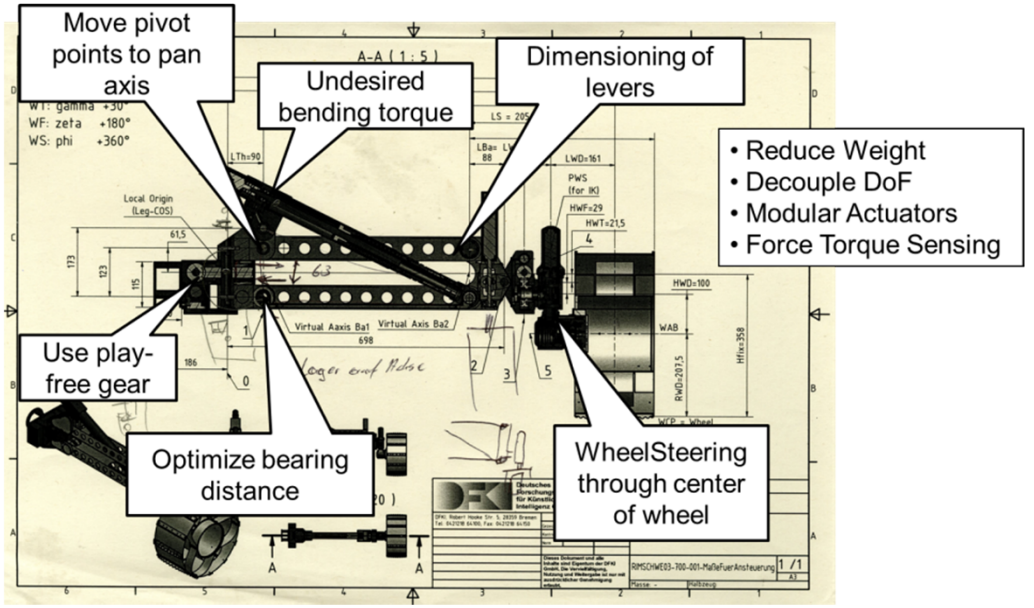


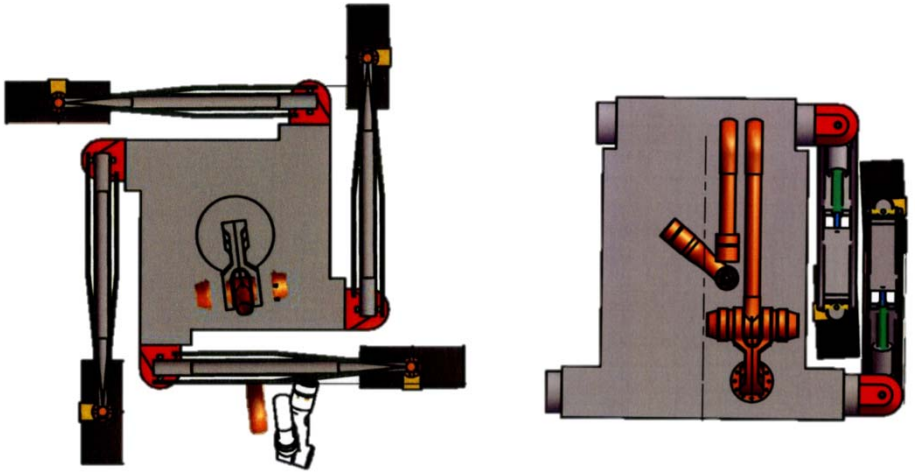


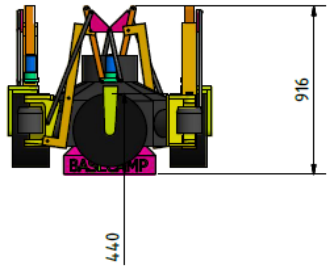
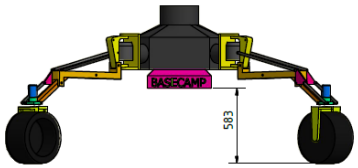
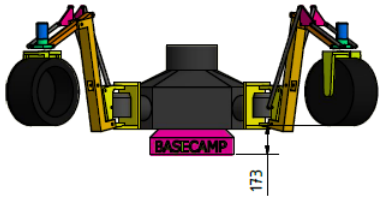
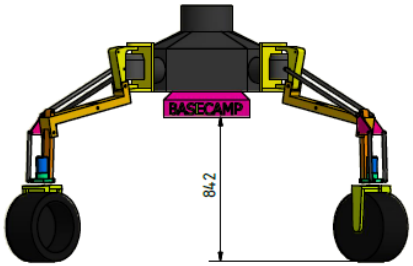
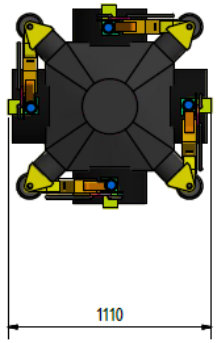
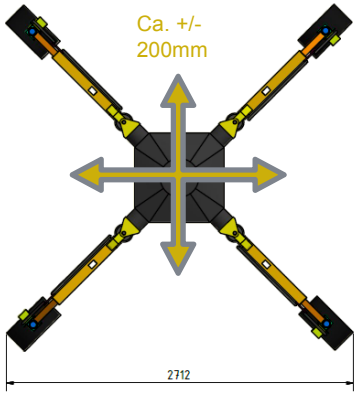
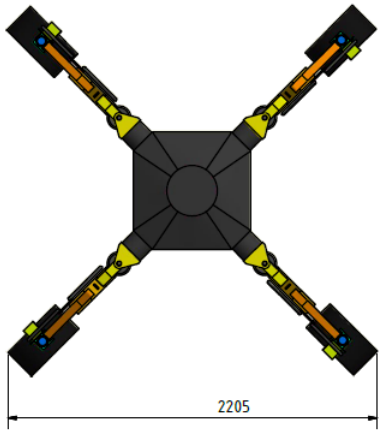
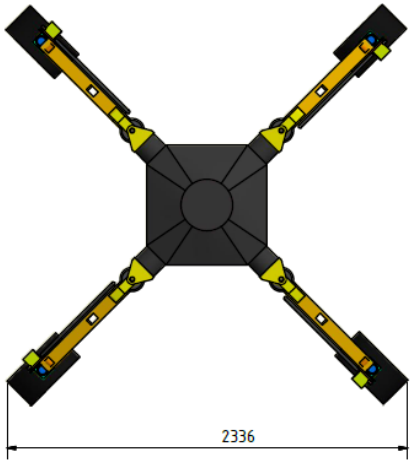
Design Studies for Design Upgrade

- Goal is a reduced, compact stow envelope
- More flexibility in body pose desired
- Asymmetric body is not optimal for manipulator usage
  - Neither for use in manipulation nor in case of locomotion support



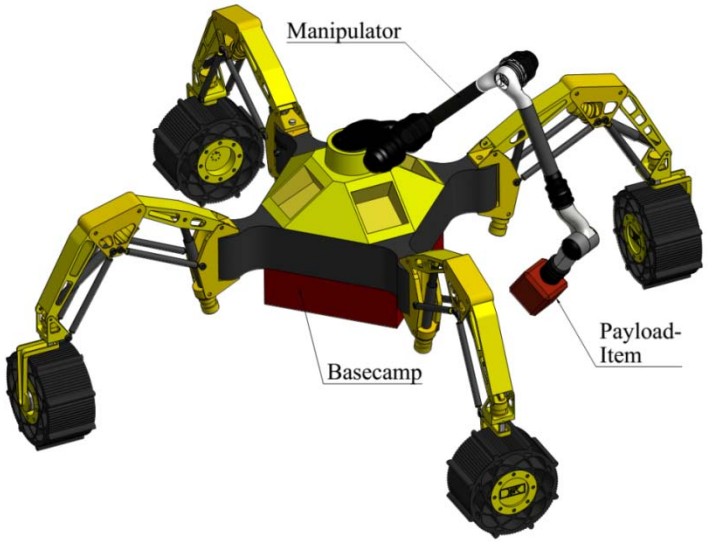


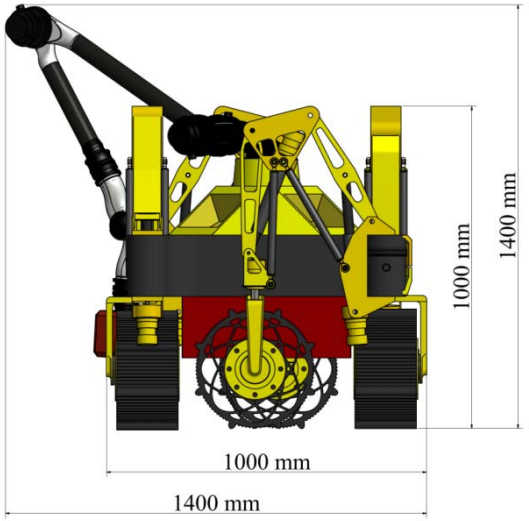


Storage	Normal	H_min	H_max
			
			

Design Improvements

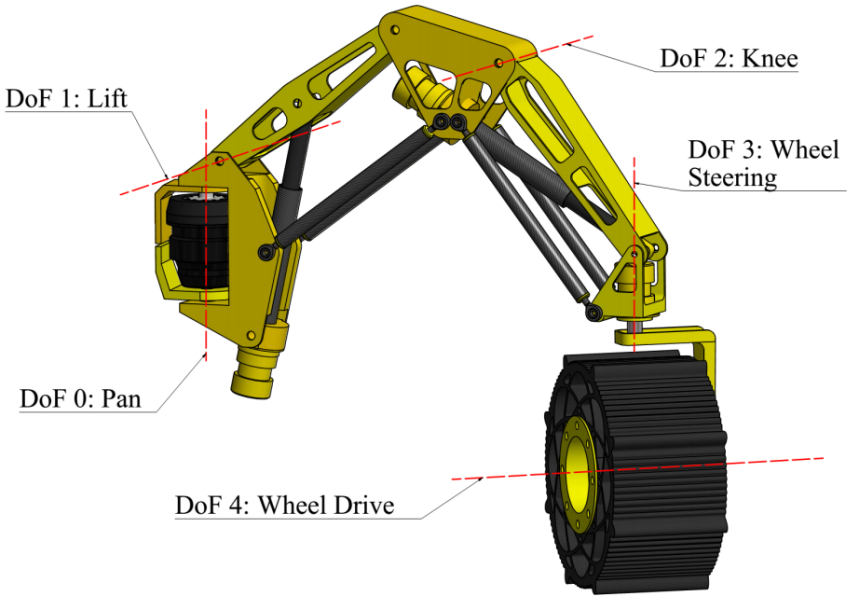
- Conceptual
  - Keep four identical Legs, symmetrical arranged around central body
  - Elastic wheels for small scale ground adaptions
  - Central manipulator for payload positioning and locomotion support
  - Base camp storage underneath body
- Project / mission requirements
  - Passive base camp needs to be picked up
  - Modular expansion using modular payloads and a common electro-mechanical interface (EMI)
- Features
  - Compact storage pose
  - Increased range of movement/work space of legs

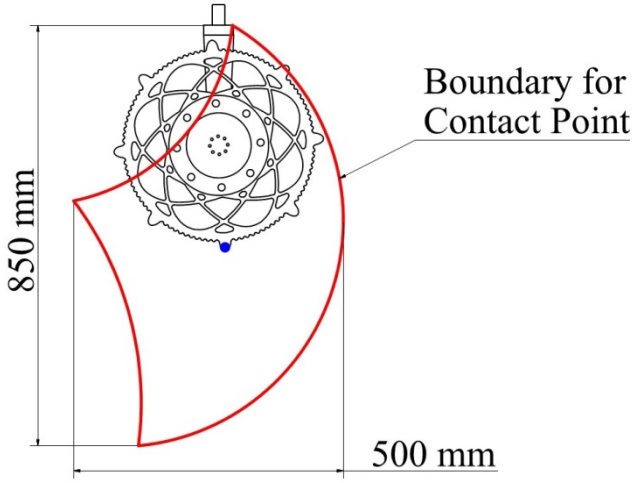




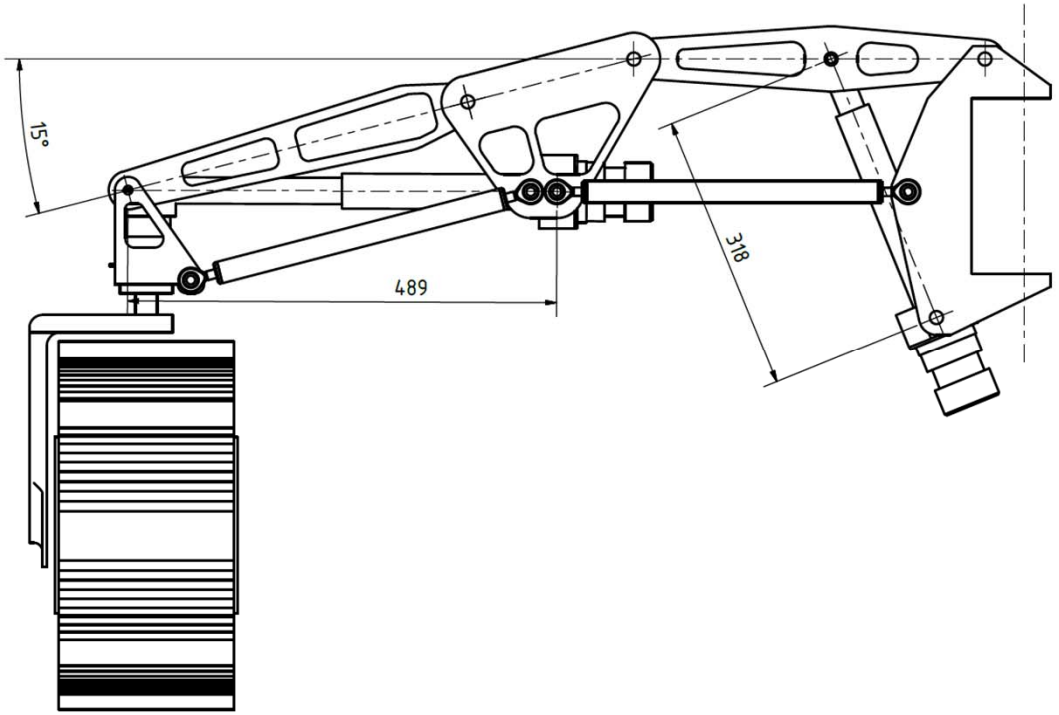
Suspension Re-Design

- Five Degrees of Freedom
  - Three positioning the wheel
  - Two for wheel orientation and wheel drive
- Advantages
  - Increased range of movement for Wheel Contact Point
  - Zero Scrub Radius
  - Linear Actuator in “pull” configuration (higher precision due to lower mechanical slackness)
- Types of actuators
  - Two linear actuators (push rods)
    - Used in serially coupled parallel structures
  - Three rotational actuators

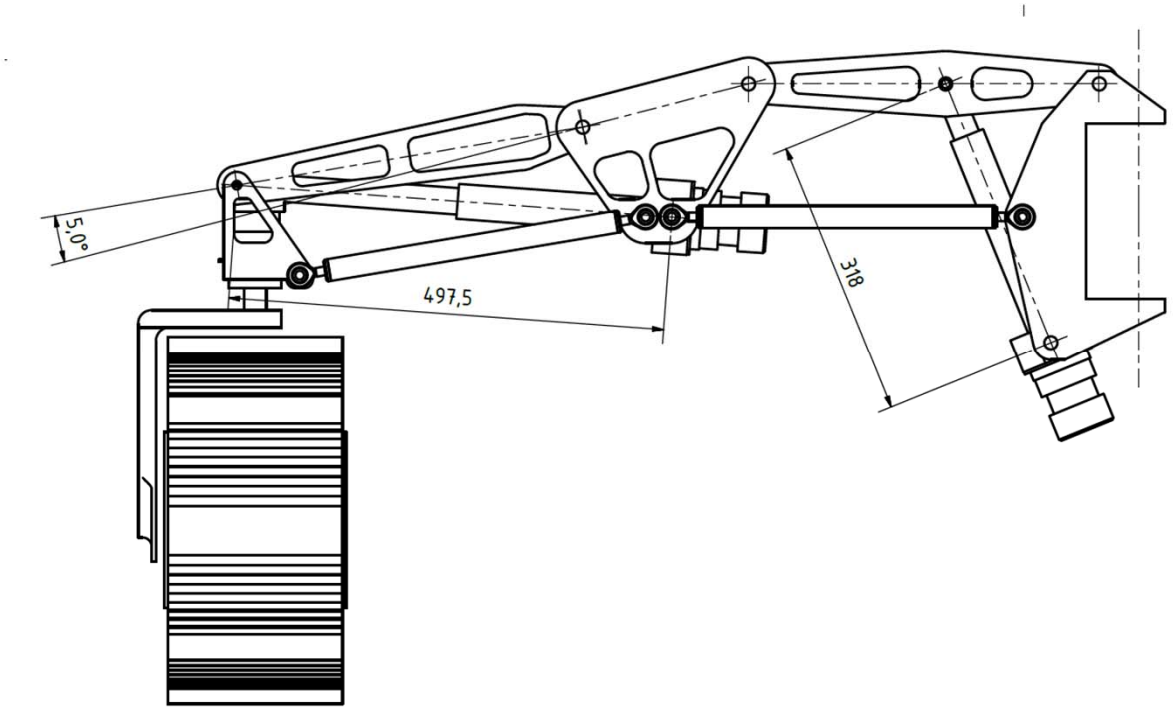




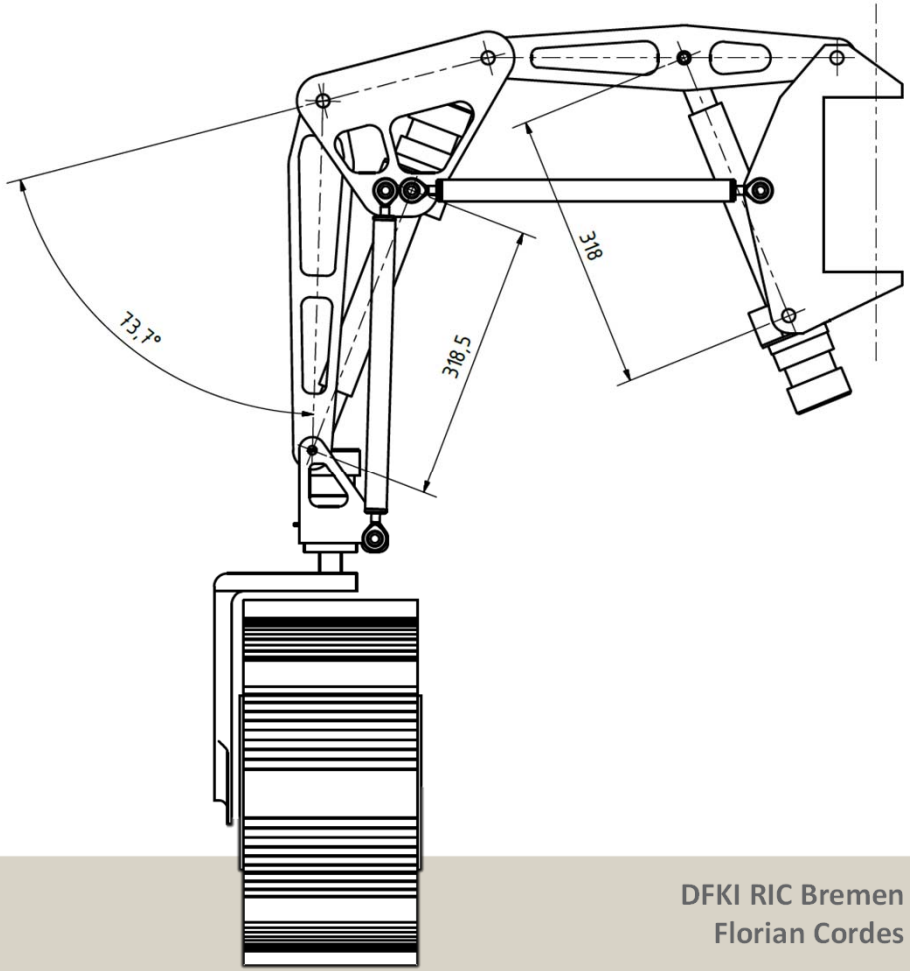
Joint Max Positions (Zero Positions)



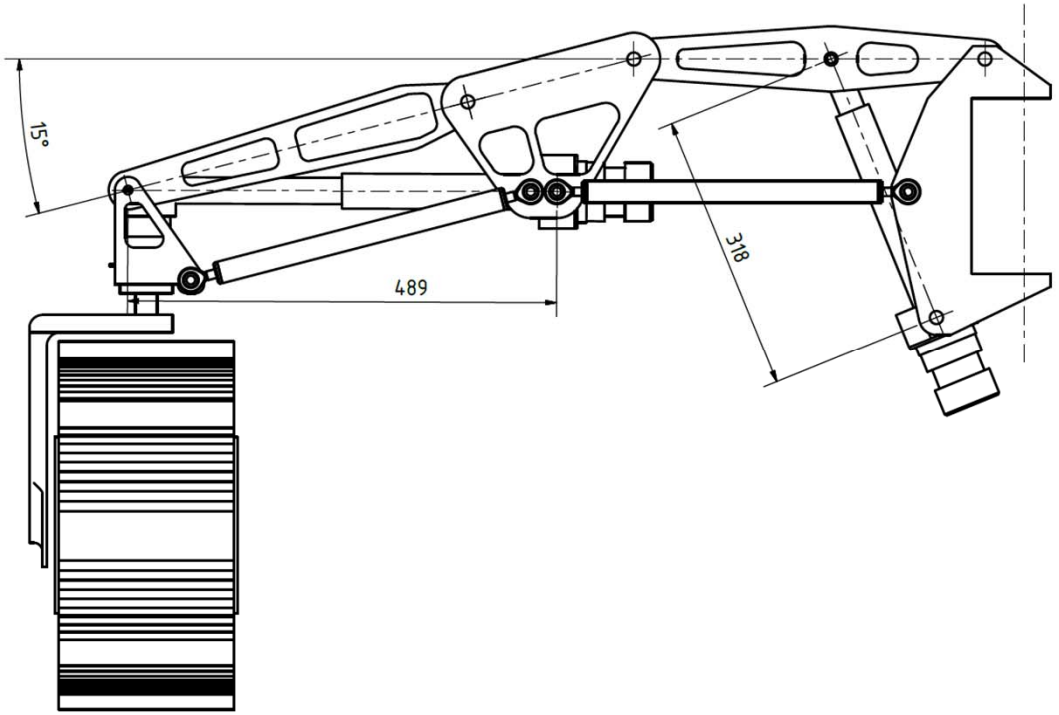
Joint Max Positions (Outer Up)



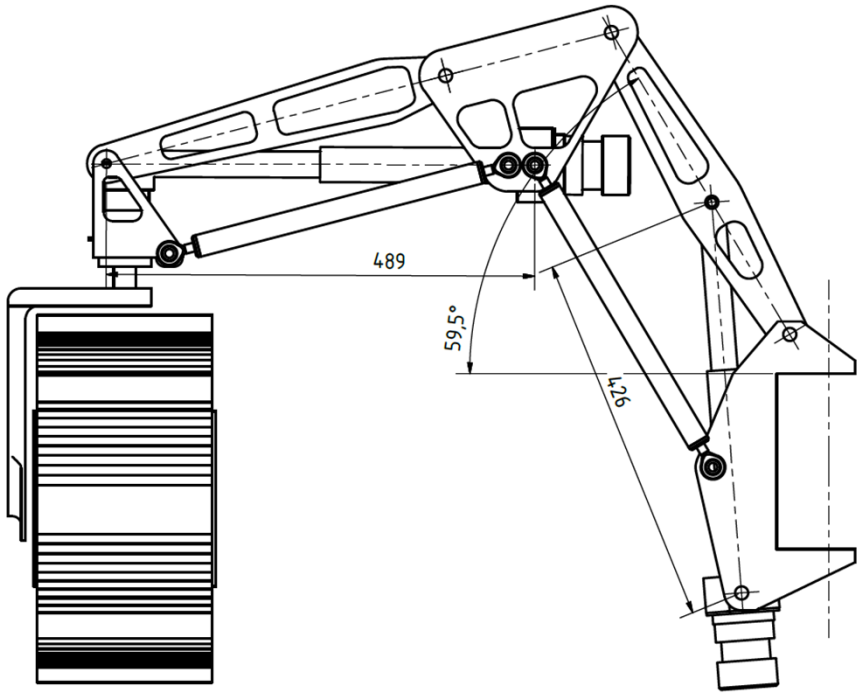
Joint Max Positions (Outer Down)



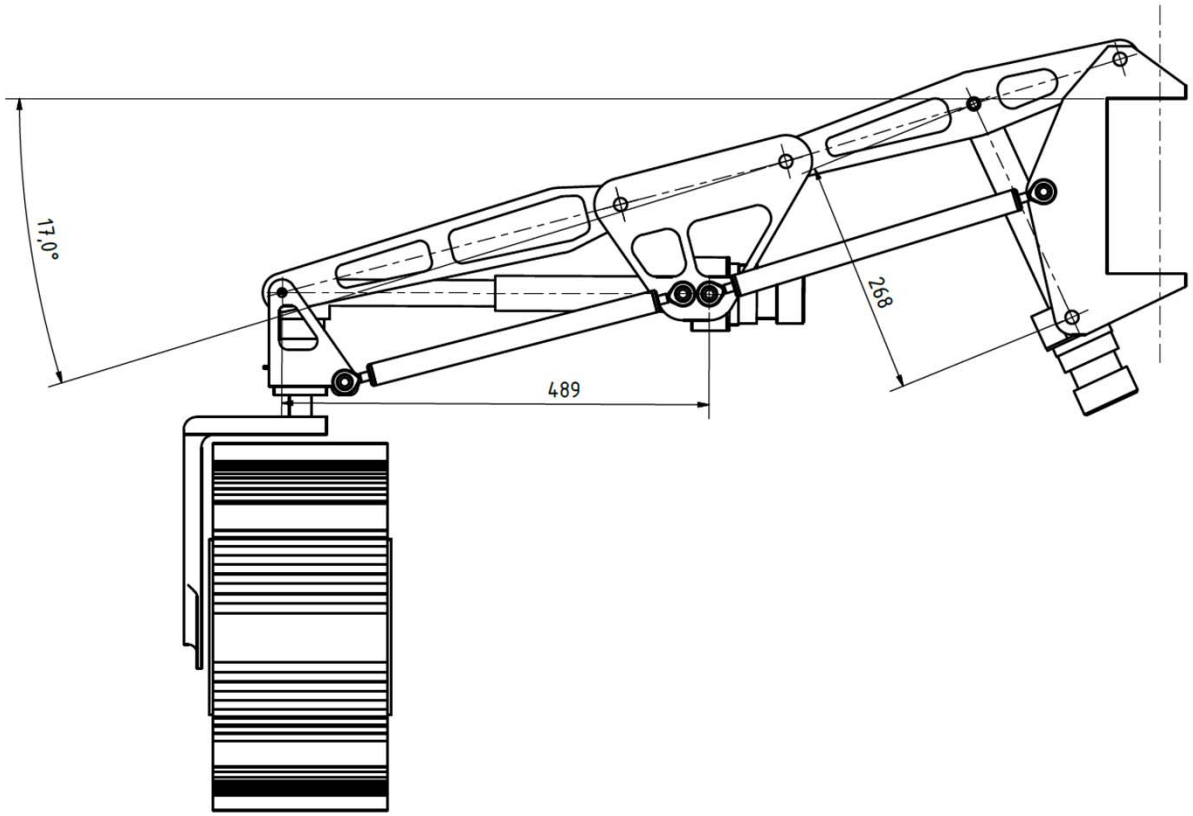
Joint Max Positions (Zero Positions)



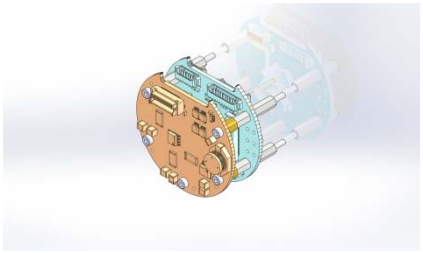
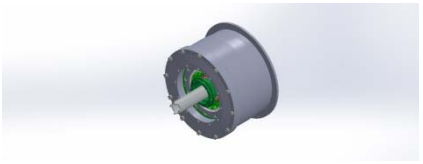
Joint Max Positions (Inner Up)



Joint Max Positions (Inner Down)

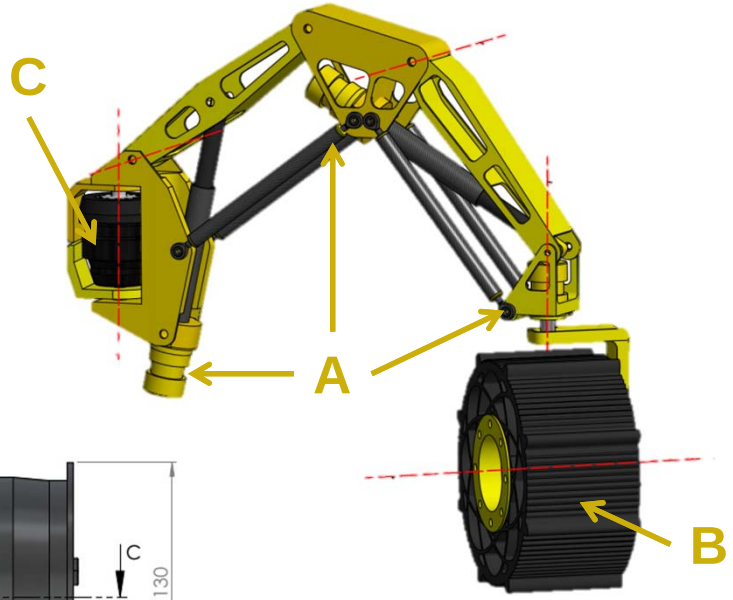


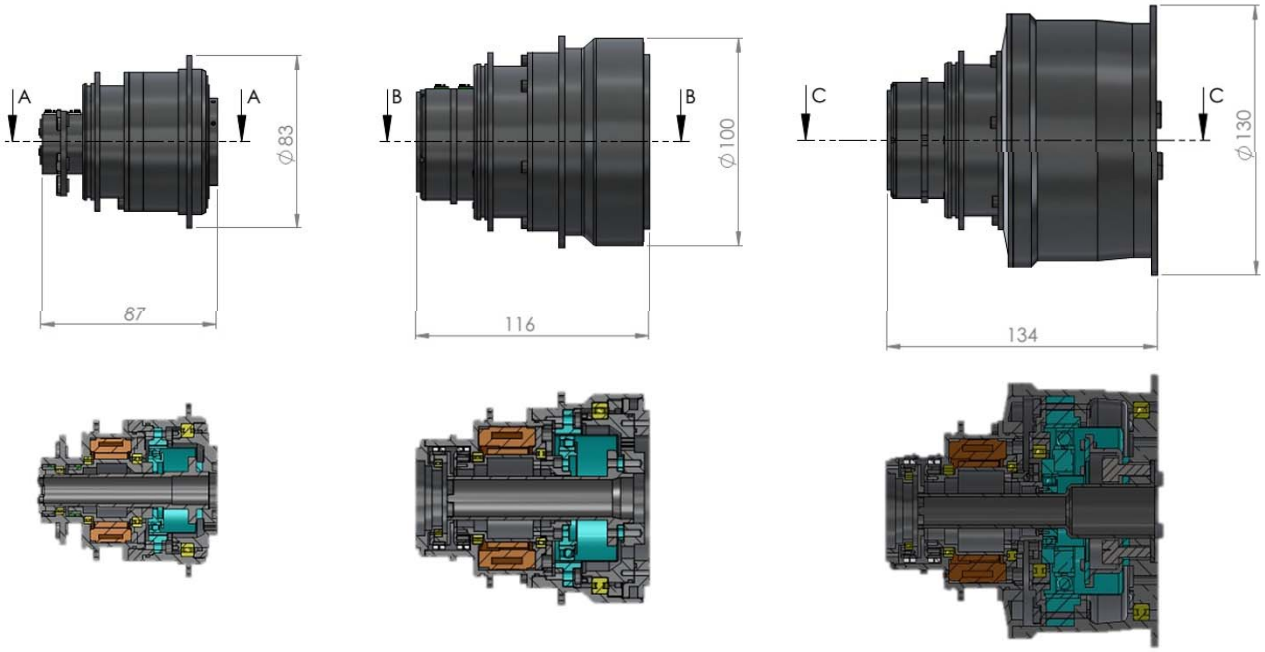
Modular Actuator Concept

Electronic	Motor	Gearbox	Options
 „BLDC-Stack“ • Power Electronics • Local Control ▪ Speed ▪ Position ▪ Current • Communication	 Motor-Module ILM50 • 0,50 Nm • 3500 rpm  Motor-Module ILM70 • 0,74 Nm • 3500 rpm	 Gearbox CPL17 • 1:30, 1:50, 1:80, 1:100, 1:120  Gearbox CPL25 • 1:30, 1:50, 1:80, 1:100, 1:120, 1:160  HighTorque Gearbox • 1:3000	 Linear-Actuator Kit

Implemented Actuator Types

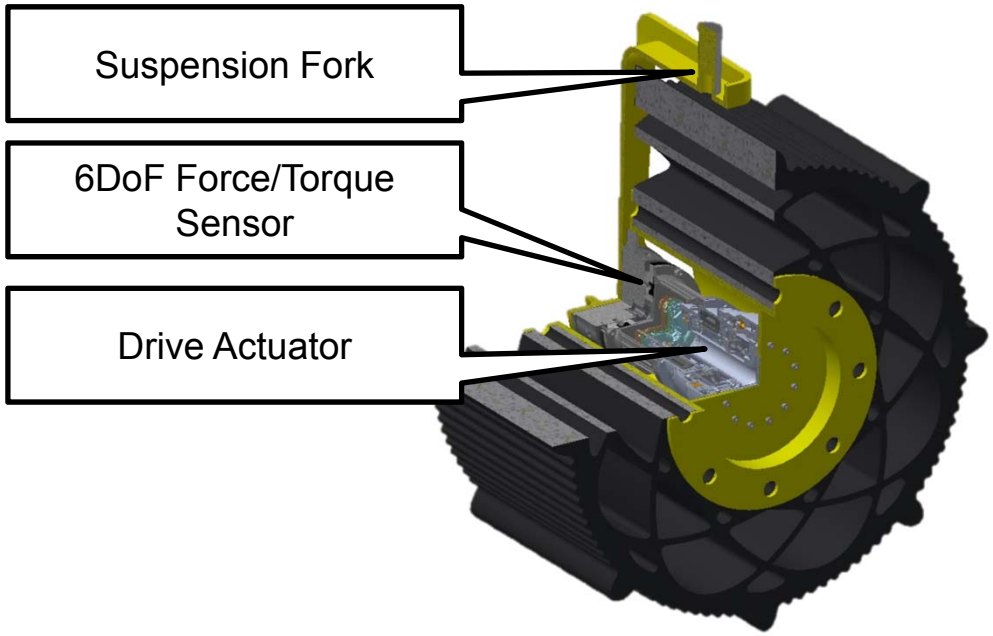
- Three types implemented
  - A nominal 29rpm / 55Nm
  - B nominal 35rpm / 74Nm
  - C nominal 1.1rpm / 433Nm
- For Lift and Knee Type A + Linear Kit

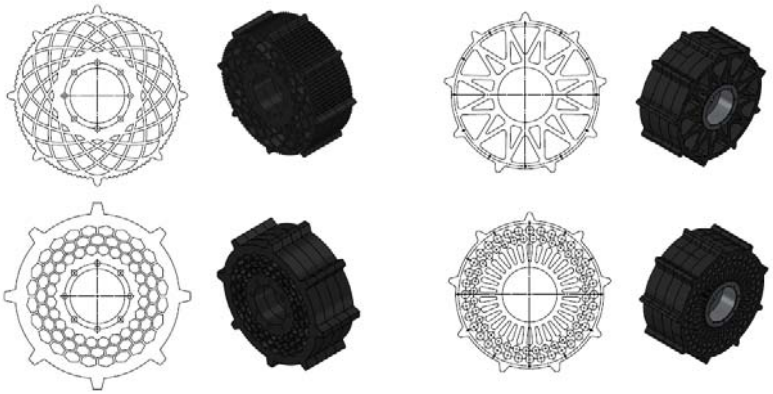


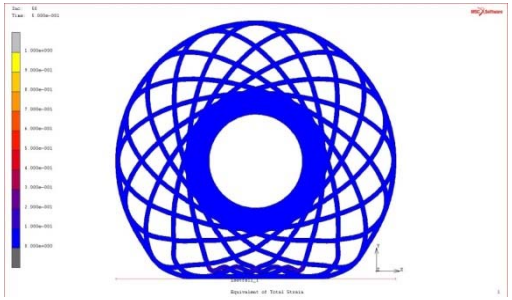


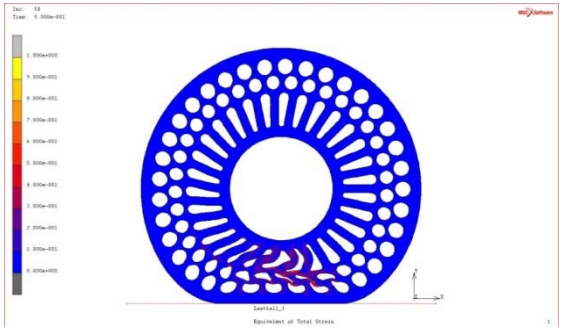
Wheel Drive and FTS

- Flexible wheel design
- Adapts to small ground irregularities
- For now: planned material is rubber
- 3 to 4 water jet cut discs allow testing different profiles and different wheel widths



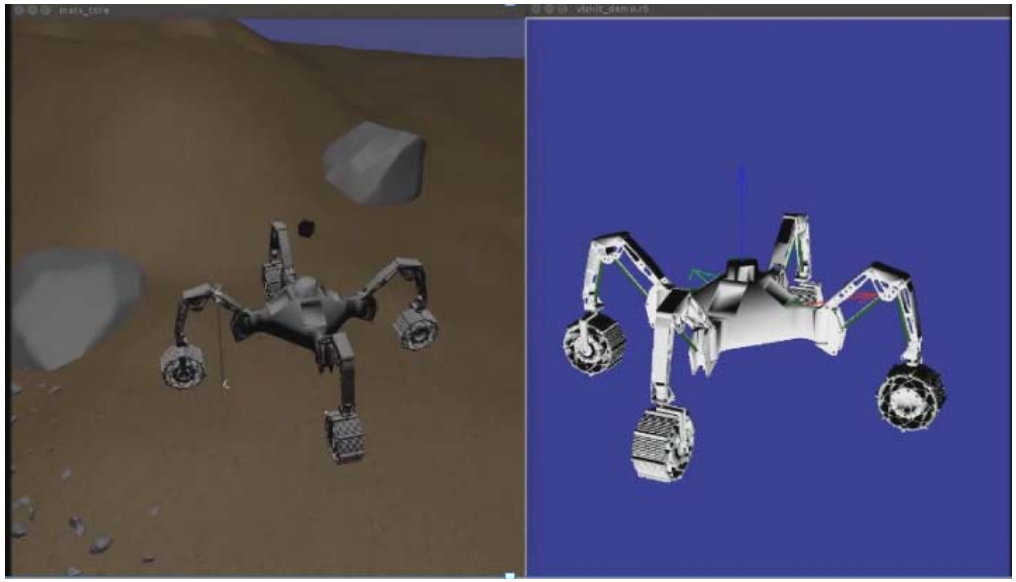






Sherpa Control – First Steps

- First version of Sherpa had own locomotion controller, HL-behaviors in Rock
- New locomotion controller integrated in Rock
  - Simulation based development
  - Modelled kinematics
  - Planar (omnidirectional) drive behavior
  - No ground adaptions so far
- Planned
  - Active ground adaption using FTS and IMU
  - Alternative drive modes



Video: Sherpa in Simulation and VizKit

Outlook / Next Steps

- Electro-mechanical integration of new suspension legs (1x Testleg)
  - Currently work-in-progress
  - Joint electronics are ready
- Low-level control
  - Joint control
  - Joint communication
  - Leg control
- Locomotion control using simulation
  - Implement adaption behaviors
  - Implement alternative locomotion modes
  - Port to physical system after electro-mechanical integration

Thank you!

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