SPACE HERITAGE:

ROKVISS

In the mid-nineties DLR developed a new generation of light weight robots (LWR) with an excellent power to weight ratio as well as impressive control features, which made the system easy to use and safe for terrestrial servicing applications. This technology was transferred to KUKA, one of the world wide leading robot manufacturers.

The same joint technology was verified in the ROKVISS (RObotic Components Verification on the ISS) experiment, from March 2005 to November 2010. A 2-dof robot arm measuring 50 centimetres in length and a weight of seven kilograms was fitted on a basic platform outside of the Russian Service Module (SM) on the ISS.

The technology experiment could be controlled either fully automatically or with telepresence operation – real-time haptic remote control from DLR in Oberpfaffenhofen, Germany. More than 500 experiments were successfully executed.

The ROKVISS robot was returned to the Institute of Robotics and Mechatronics for analyzing the effects on the mechanics, especially the lubrication of the gears. The results of these analyses led to design improvements of the CAESAR joints.

ROKVISS (2005-2010)

DLR at a glance

DLR is the national aeronautics and space research centre of the Federal Republic of Germany. Its extensive research and development work in aeronautics, space, energy, transport and security is integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency, DLR has been given responsibility by the federal government for the planning and implementation of the German space programme. DLR is also the umbrella organisation for the nation's largest project management agency.

DLR has approximately 8000 employees at 20 locations in Germany: Cologne (headquarters), Augsburg, Berlin, Bonn, Braunschweig, Bremen, Bremerhaven, Dresden, Goettingen, Hamburg, Jena, Juelich, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Oldenburg, Stade, Stuttgart, Trauen, and Weilheim. DLR also has offices in Brussels, Paris, Tokyo and Washington D.C.

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CAESAR

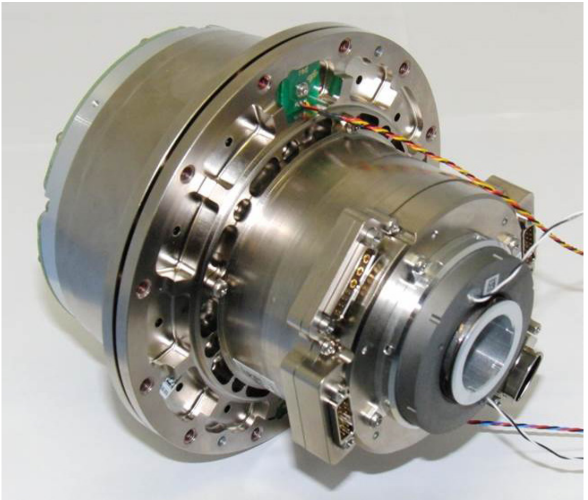
Compliant Assistance and Exploration Space Robot

DLR

CAESAR - Space Robotics

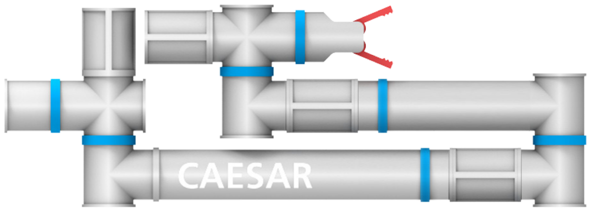
With the development of the space-qualified robotic system CAESAR (Compliant Assistance and Exploration SpAce Robot) the Institute of Robotics and Mechatronics at DLR (DLR RM) continues the work on on-orbit servicing that began with DEOS. The seven degrees of freedom (DoF) robotic system is intended to be capable of catching satellites in LEO/GEO, even ones that are in tumbling, and/or non-cooperative states. The dexterity and sensitivity of CAESAR enables assembly, maintenance and repair of satellites. Rad-hard design and a one-of-two fully redundand system ensure lifetime and reliability during the mission.

For CAESAR, DLR RM is developing the entire robot system including the robotic hardware and core functionalities for On-Orbit-Servicing. These include complete control of the robot, on-board task management and stereo-based visual servoing, for instance to perform high precision assembly tasks. For grasping a non-cooperative satellite, a robust, dynamically adjustable robot path is generated on ground. The basis is a prediction of the satellites tumbling at the time of grasping. Once the satellite has been grasped, the total system is stabilized by the robot arm so that no more relative motions occur between the two satellites. Dedicated robotic activities are to be performed semi-autonomously, in teleoperation, including telepresence mode.

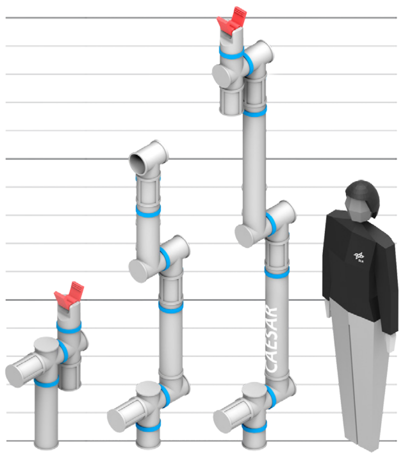


CAESAR Joint

Building Block Concept: The key to CAESAR's high performance are intelligent impedance and position controlled joints. These joints are building blocks for setting up diverse robot kinematics depending on the different mission goals. The scalability of the robot is determined by the number of joints and the length of the links. CAESAR's seven DoF enables it to meet the dexterity and the kinematic redundancy requirements.



CAESAR can be folded for storage on the servicer satellite



Configuration options in any number of joints and link lengths

Sensor based joint state control is implemented to ensure smooth and accurate motion as well as sensitive reaction to external forces.
High resolution magnetic encoders for both motor shaft position and absolute link position in combination with high controller sampling rate yield excellent trajectory accuracy and disturbance rejection. A structural integrated torque sensor delivers high quality torque values free of frictional effects in the bearings or the gear. In combination an active vibration damping on joint level as well as cartesian control of a compliant robot behavior is possible.

Cartesian control of the robot Tool Center Point (TCP): Extending the impedance controller, the CAESAR arm can behave compliantly, while maintaining TCP position. The compliant behavior is triggered if any part of the robot detects contact with the environment. Compliance is a significant safety feature in dynamic environments or in close vicinity to the astronauts.

Technical Specification of CAESAR

Manipulator	
Joint Position Sensor Resolution	82.830 inc / 320°
Motor Position Sensor Resolution after Gear	11.650.644 inc / 320°
Length of Manipulator Arm	2.4 m + x (7dof)
RA Mass	~ 60 kg
Thickness of Aluminum Housing	2mm
Internal Databus	Deterministic, real-time EtherCAT with 100MBit/s
Range of Motion	320° for all axis
Joint Output Torque	80Nm for all axis
Joint Velocity	Up to 10°/s
Environment	
Operational Temperature	-20°C to +60°C
Non-Operational Temperature	-50°C to +80°C
Radiation Hardness	40krad TID (with additional shielding 100 krad TID)
Mission Time	Up to 10 years