SMALL EXPLORATION ASSISTANT ROVER

Technische Universität Berlin

Developing Technologies for Space on a Terrestrial System: A Cost Effective Approach for Planetary Robotics Research

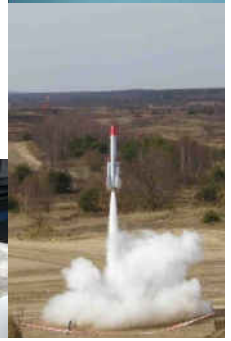
1st Symposium on Space Educational Activities | Lennart Kryza – TU Berlin | Dezember 10th 2015

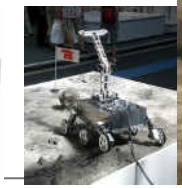
Agenda

- The Chair of Space Technology at the TU Berlin
- SpaceBot Cup Competition
- Team Structure of Team SEAR
- System SEAR – Hardware and Software
- Internal Developments and Research in Project SEAR
- Conclusion

The Chair of Space Technology

- Chair of Space Technology was founded in 1963
- Research activities in all segments of a spacecraft mission
- Research focus on miniaturization of small satellites components
- Over 60 staff members
- Over 120 students per year
- Two study programmes
  - Aerospace Engineering
  - Master of Space Engineering (Int.)





SpaceBot Cup Competition

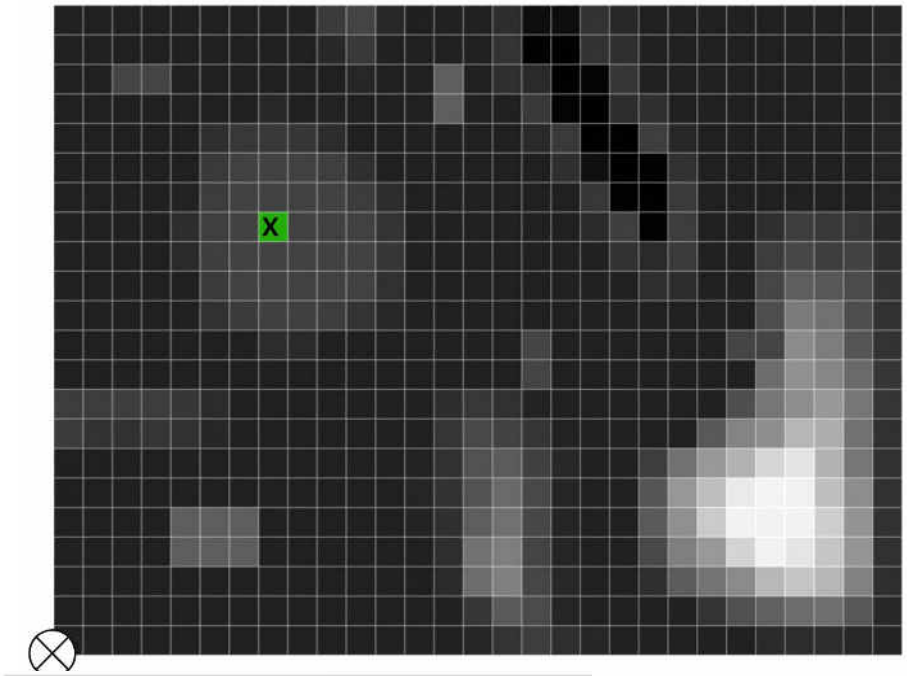
- Initiated by the German Aerospace Center (DLR) in 2013
- 10 Teams compete in a planetary exploration scenario
- System had to autonomously fulfill three tasks within one hour
- Communication with the robot was restricted:
  - Delay of 2 seconds in both directions
  - Uplink only during checkpoints +
  - No uplink for 4 minutes during simulated blackout

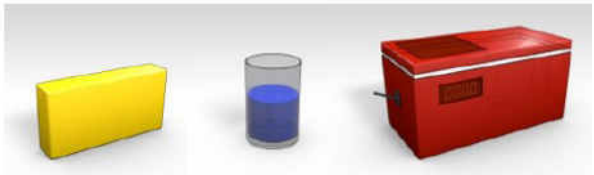
SpaceBot Cup Competition

Robotic Systems at the SpaceBot Camp 2015 [source: DLR]

Mission Scenario

- Teams are provided with a rough map of the field
- Robots have to autonomously navigate and map the field more accurately
- Three objects have to be found, a battery, cup and station
- Battery and cup are to be brought to the station for assembly
- After assembly, a lever is to be pulled at the side of the station

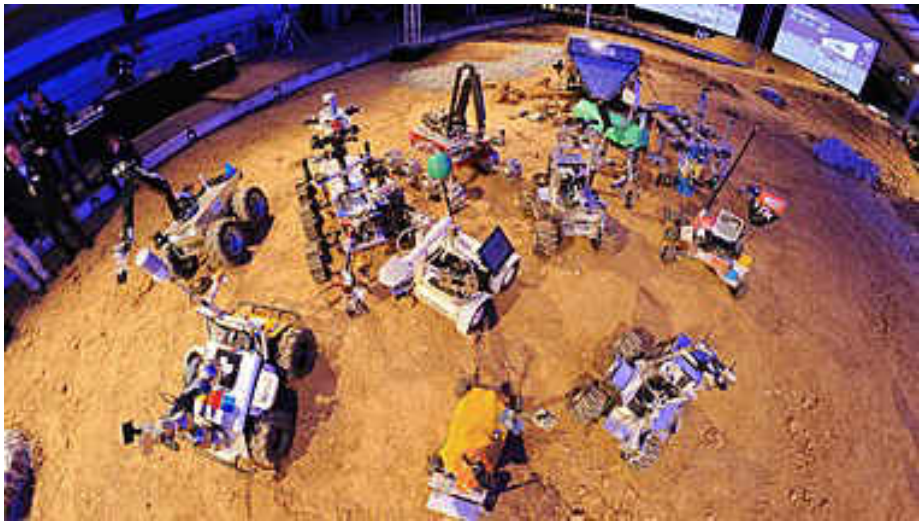




Rough map and objects [source: DLR]

SpaceBot Cup 2013

- Kick-Off meeting in march 2013, competition in November
- Developments at the TU Berlin began in April with project SEAR (Small Exploration Assistant Rover)
  - ➔ Extremely short development time!
- All teams had severe problems during the cup
- Most notable problem: Communication



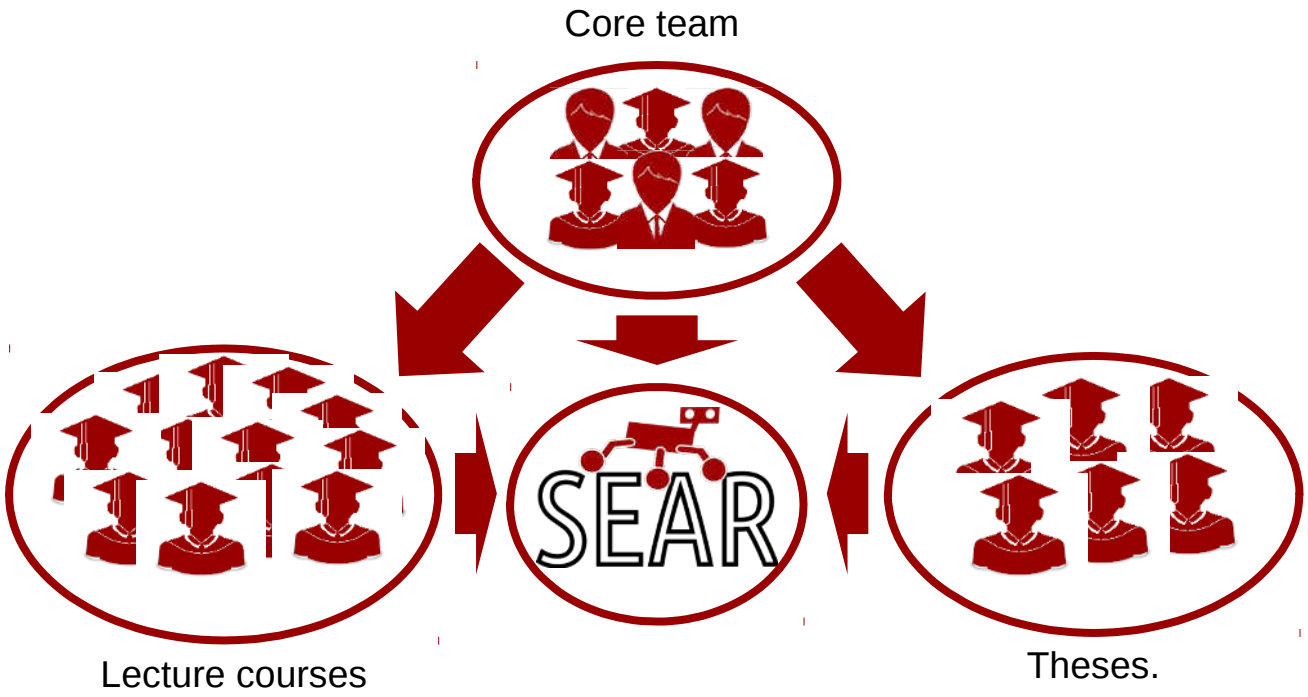
DLR SpaceBot Cup 2013 [source: DLR]

SpaceBot Camp 2015

- In 2014, the SpaceBot Cup 2015 was announced. Project SEAR had been kept alive in lecture courses and by thesis
- The scenario stayed the same, but one important difference was introduced:
- Teams had to undergo a qualification in order to be allowed to compete at the competition, qualification was held two months prior the actual cup
- Requirement for cup: min. 4 out of 10 teams had to qualify
- Three teams passed the qualification process (including SEAR)
- Instead of the SpaceBot Cup, a performance presentation (SpaceBot Camp 2015) was organized with the same scenario

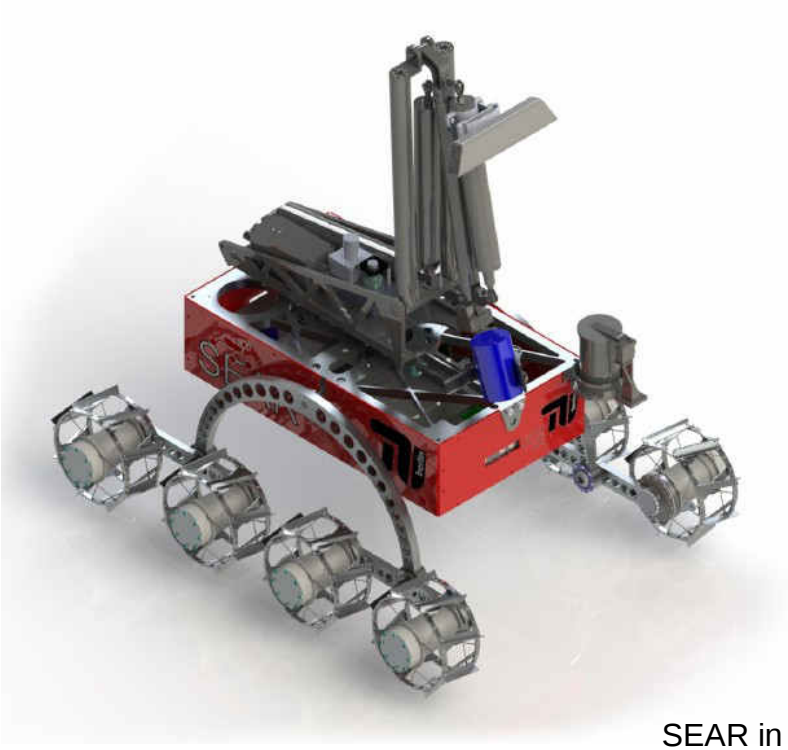
Team structure of project SEAR

- Core team with scientific and student
- Major parts are also developed in lecture courses and theses
- More than 50 students have actively participated in the project since 2013



SEAR 2013

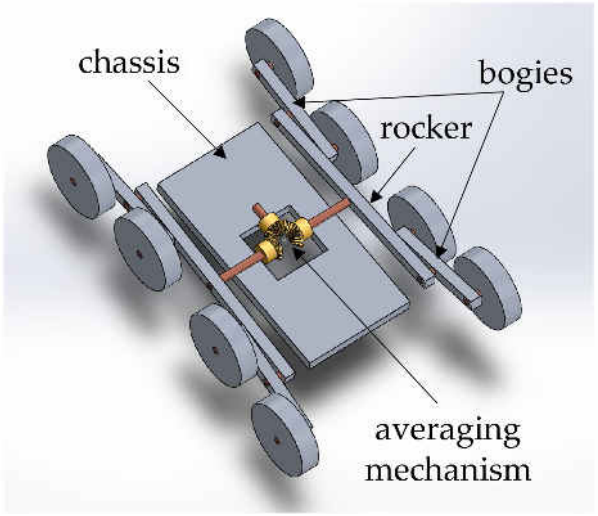
- Configuration resembles an actual rover
- Microsoft Kinect cameras were used as visual senors
- The manipulator was purchased in order to save development time
- Electronics were kept simple for the same reason; energy source is a 20 Ah 24V LiFePO4 battery, DC/DC converter provide 12 V and 5 V bus



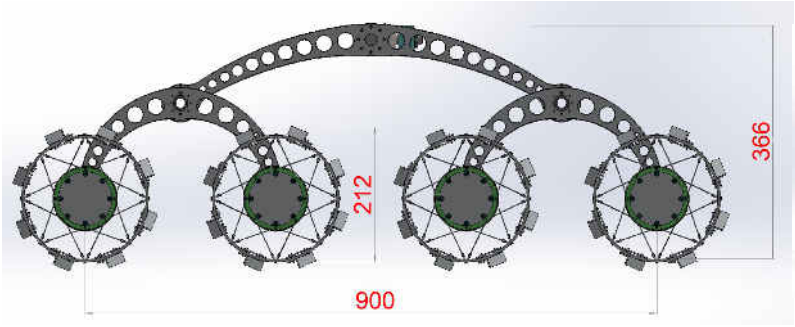
SEAR in 2013

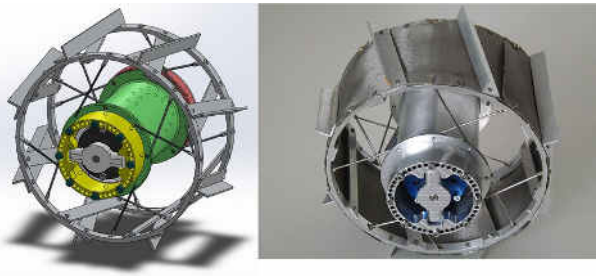
SEAR – Locomotion

- SEAR's locomotion system is based upon a rocker-bogie system
- Ability to navigate every terrain which is to be expected
- Individually powered wheels with Faulhaber motors



Rocker-bogie system

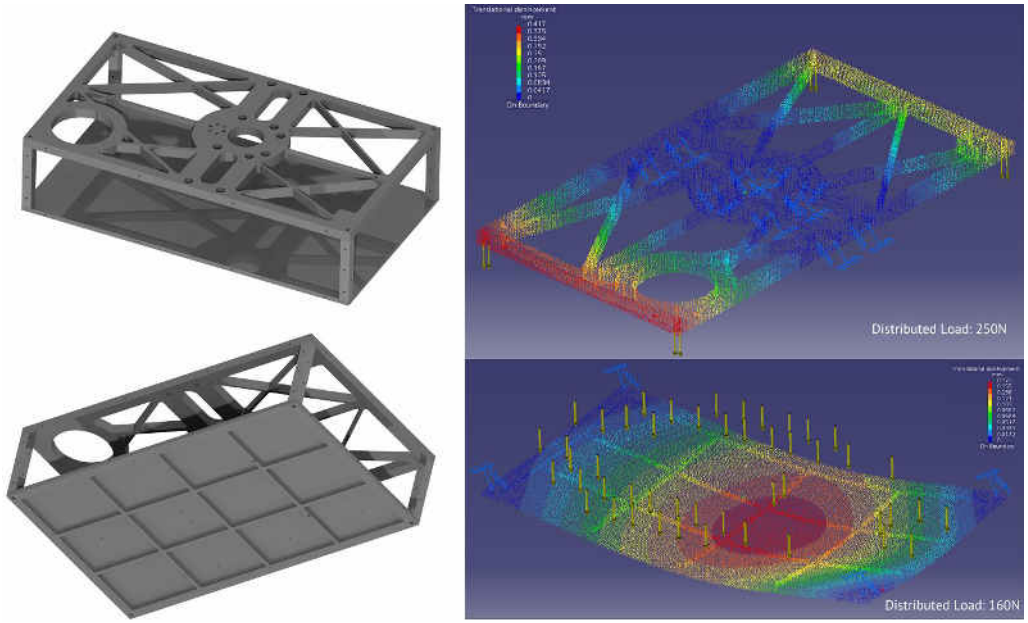




Locomotion and wheels

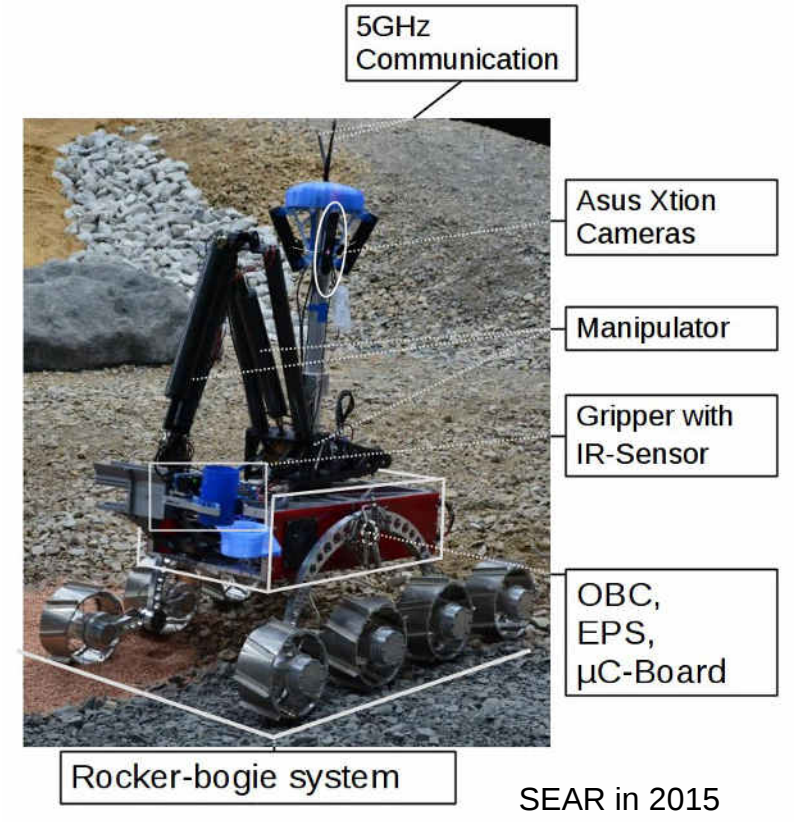
SEAR – Corpus

- The corpus contains all electronics, the OBC and peripheral processing units
- Aluminum was used as material for gaining a light and sturdy structure
- Development was conducted in lectures and by student employees
- Mechanical load analyses guarantee that the structure withstands expected loads



Corpus and mechanical load analysis result

SEAR 2015

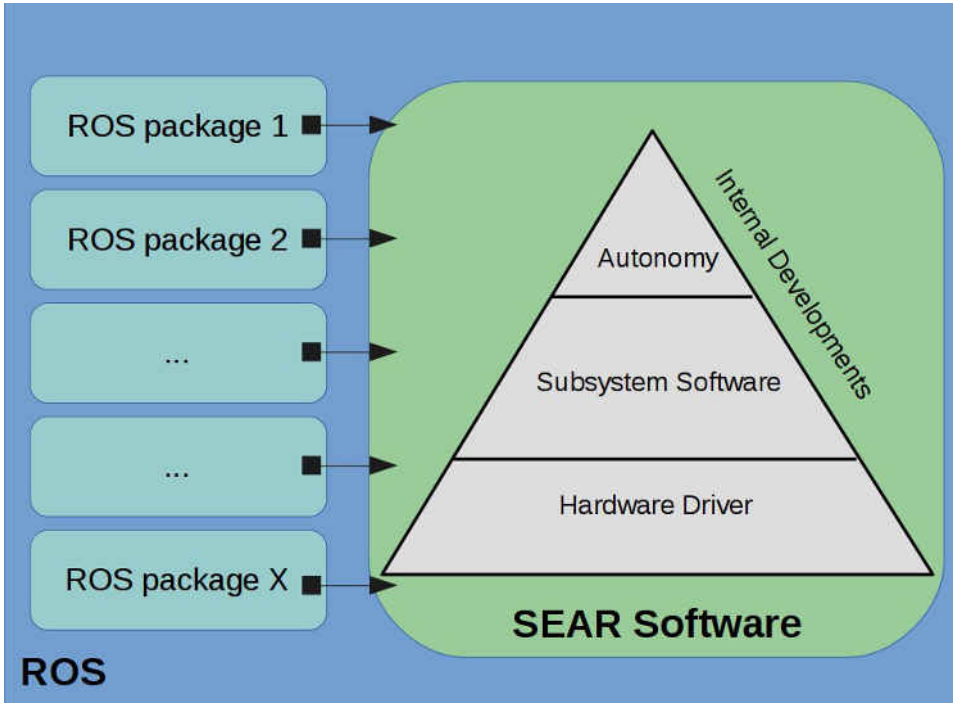


SEAR in 2015

- Basic configuration of SEAR stayed the same, but crucial systems were revised
- New sensors: Asus Xtion cameras (improved performance)
- Camera mast for better perception
- 5 GHz communication
- Gripper cam and IR-Sensor for autonomous grasping

SEAR – Software

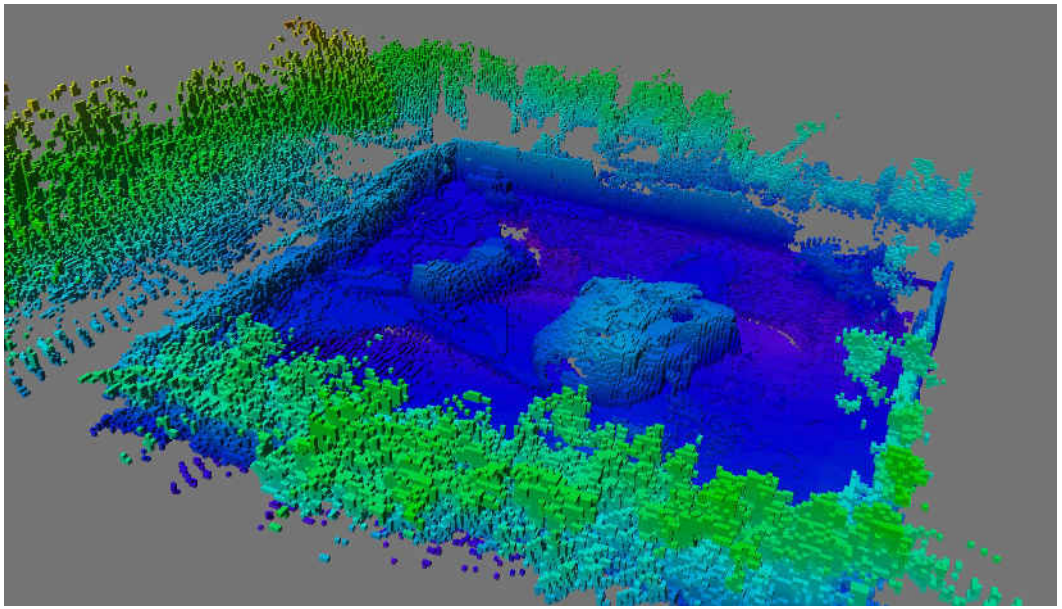
- Software is based on ROS (Robot Operating System)
- ROS provided software environment for development and operation
- Many ROS packages could be used for the rover, decreasing implementation time
- System and mission specific software are internal developments



SEAR software architecture

SEAR – Navigation and Mapping

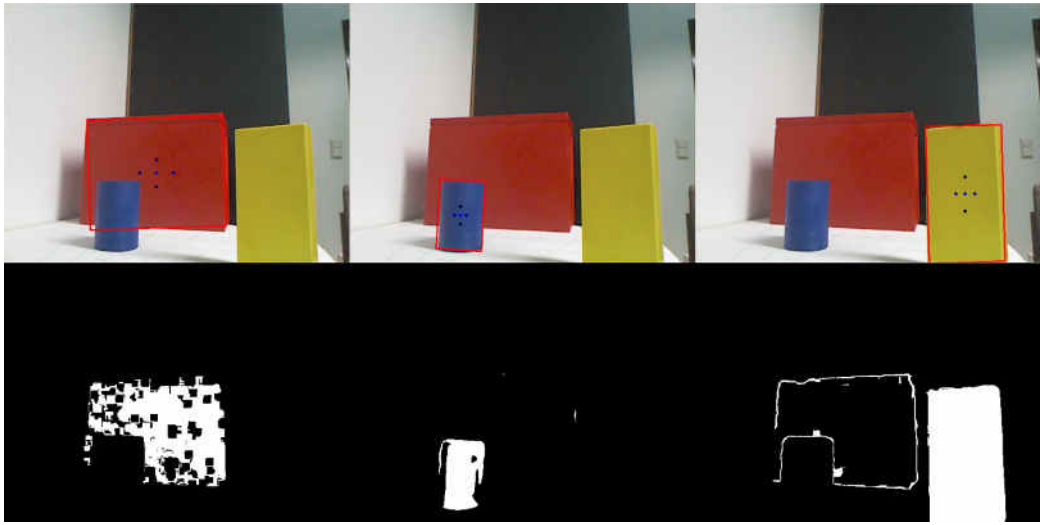
- SEAR navigation and mapping software are external developments but were adjusted for the system
- ROS package *move_base* [1] is used for path planning
- *RGBDSLAM* [2] is used for simultaneous localization and mapping
- Asus Xtion cameras are used for as visual sensors, providing RGB- and depth images



SEAR mapping result of qualification field

SEAR – Object Recognition

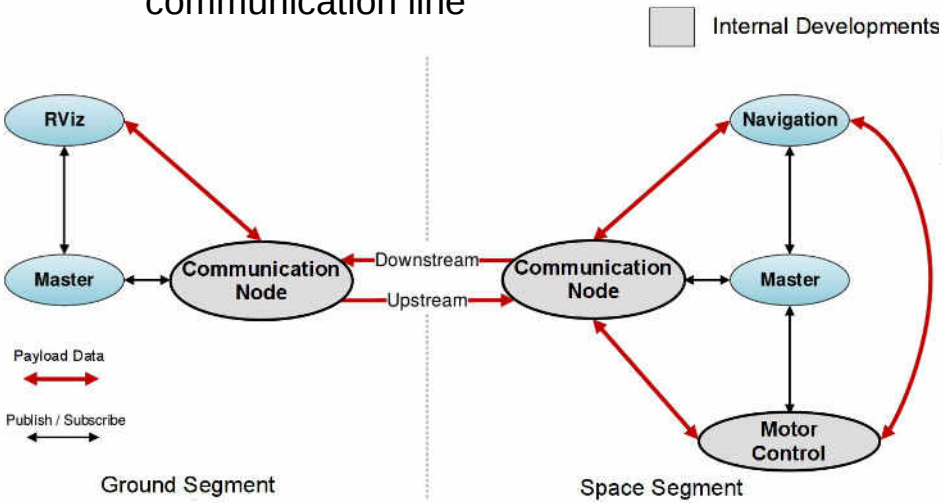
- The rover has to be capable to autonomously find, identify and locate objects
- Object recognition is based on blob detection: Color is the main indicator for potential objects
- All given parameter are taken into account: Color, shape and size. Depth information is used for localization and orientation
- Cascade algorithms are used with machine learning in order to confirm candidates

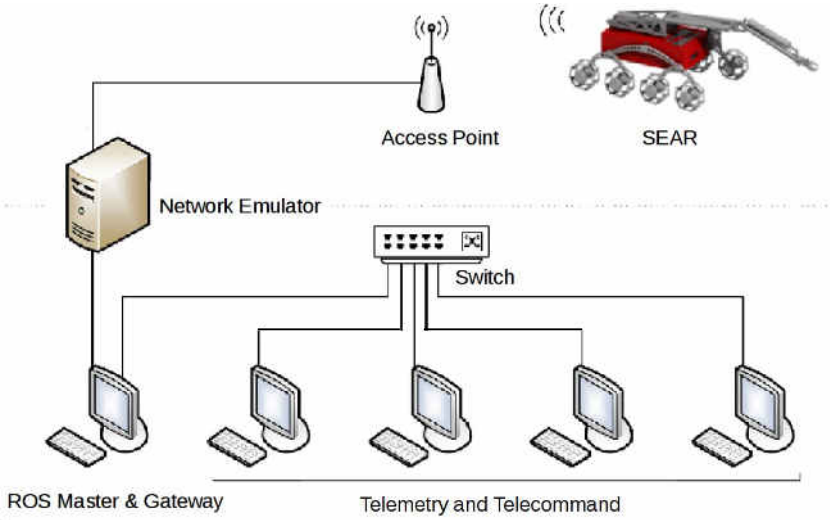


Object recognition results

SEAR – Communication

- Separation of Space and Ground segment by network emulator, simulating spacial distance
- ROS is inherently not fitted for delayed communication line

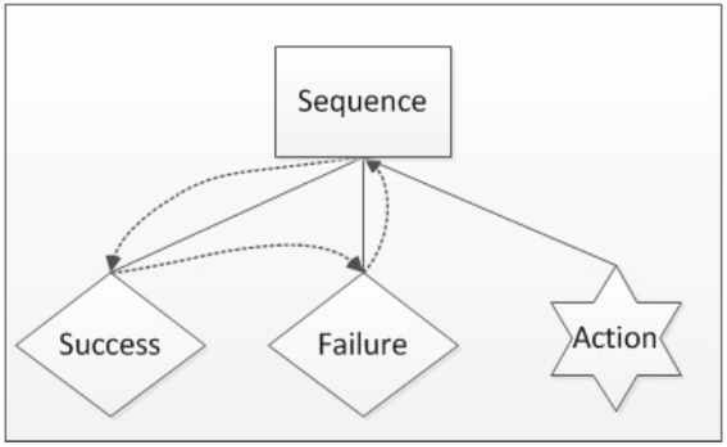


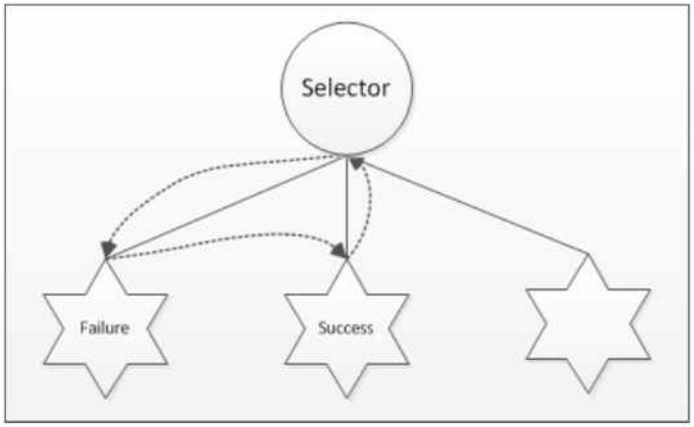


- Communication Nodes on both sides are needed for stable communication and commanding
- Use of UDP based communication

SEAR – Autonomy

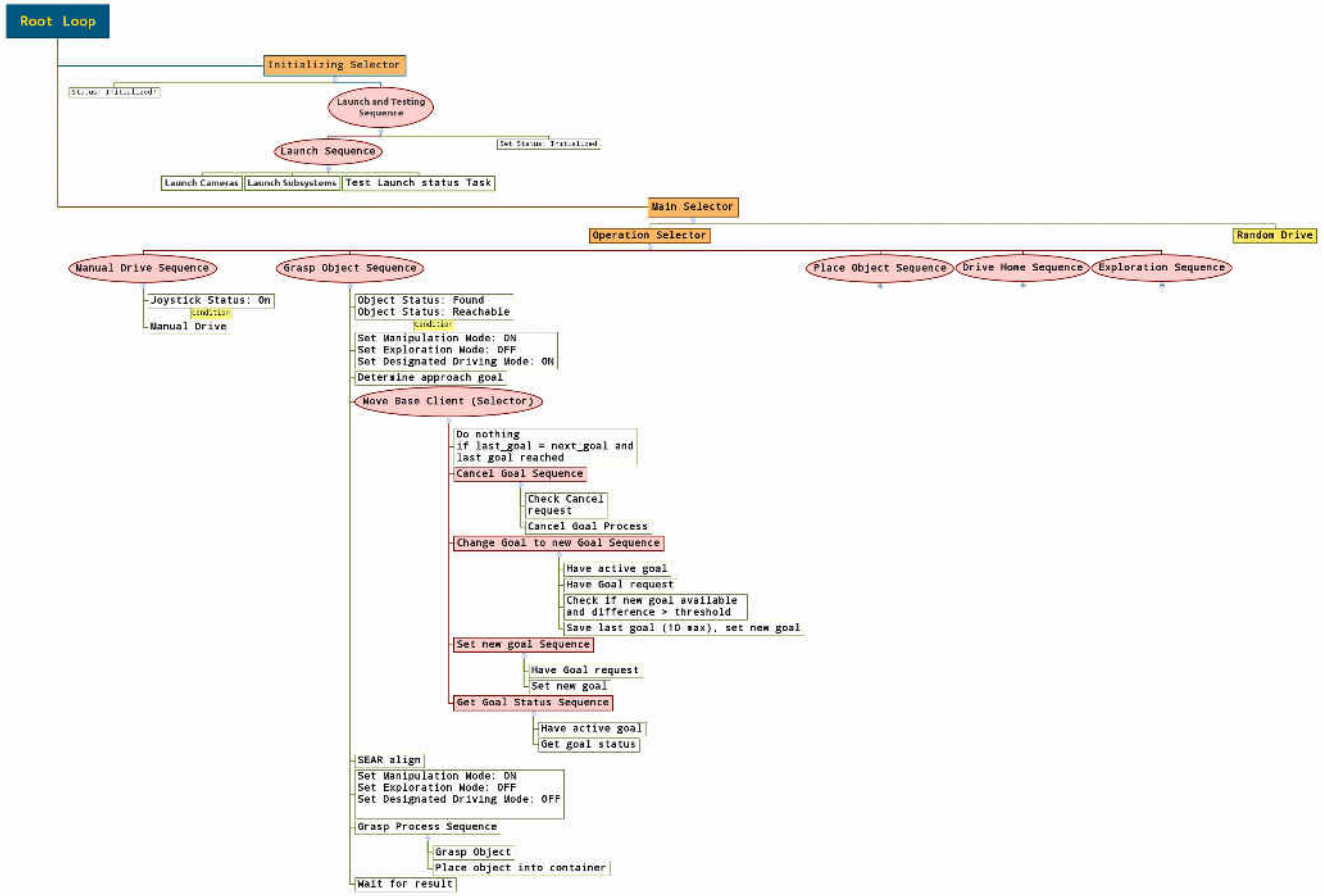
- Hierarchical autonomy approach: Task Management for the decision making process + Subsystem autonomy
- Behaviour trees (BT) are used for decision making, approach originates in computer game industry
- Basic logic elements can be used to flexibly design a complex behaviour tree
- Each element represents a tree in and of itself





Two examples of BT elements [3]

SEAR – Behaviour Tree



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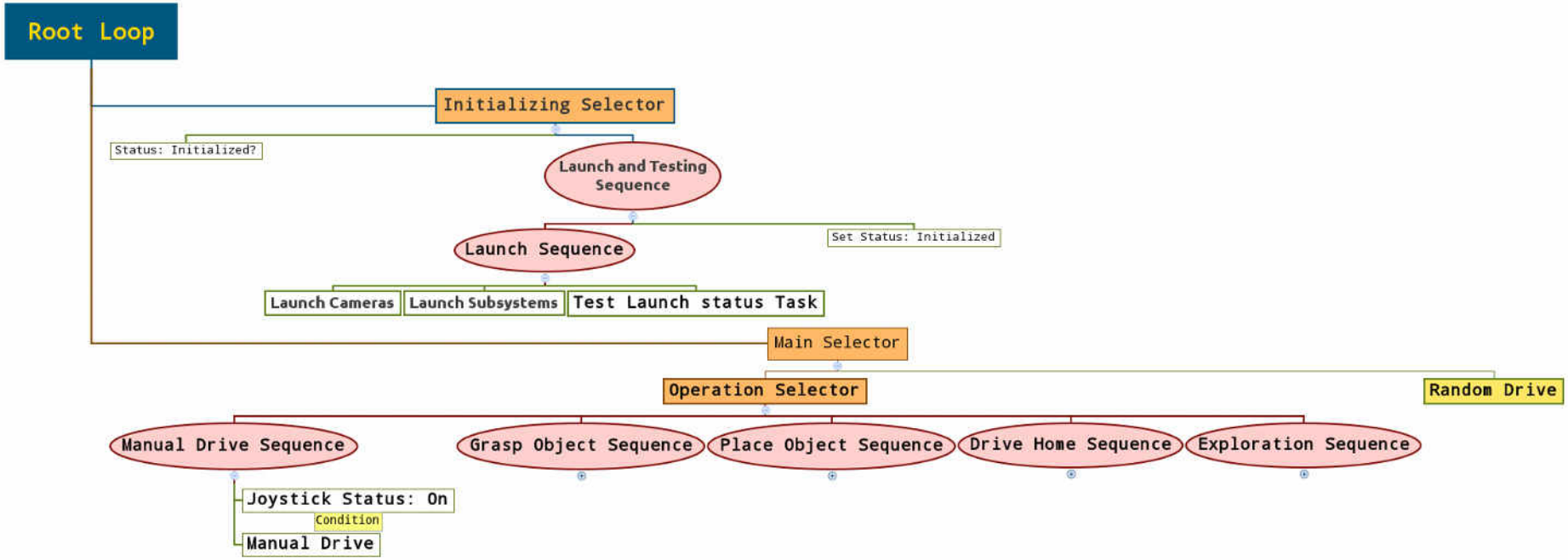
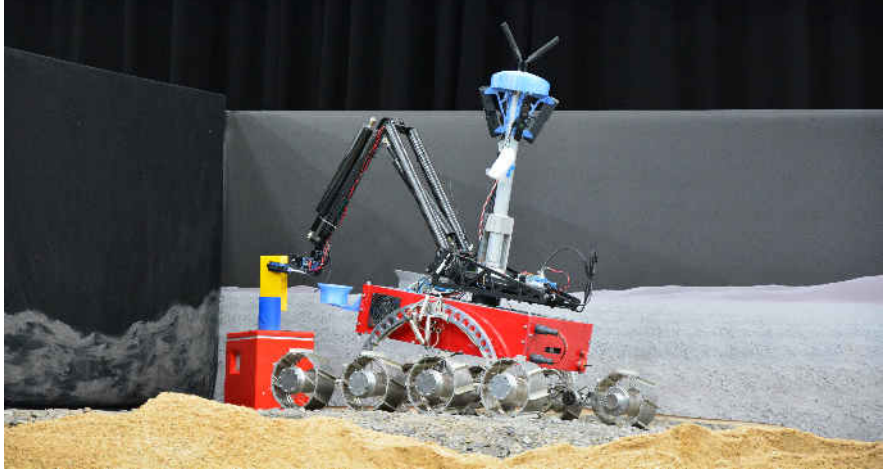


Conclusion

- SEAR is a planetary rover which is based on terrestrial technology
- Analogy between sensor data allows researching specific space mission scenario and subsystems with high degree of realism
- Developing autonomy for an planetary scenario is almost independent from the components or sensors which are used
- In the future, satellite hardware will be integrated into SEAR in order to slowly convert it to an actual space system
- Other mission scenarios are planned to be developed and tested, along the way extending its capabilities



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Thank your for attention!

References

(1) move_base
[Online]
http://wiki.ros.org/move_base

(2) RGBDSLAMv2
[Online]
http://felixendres.github.io/rgbdslam_v2/

(3) Behavior Trees for Hierarchical RTS AI. Stephan Delmer.
[Online]
https://www.smu.edu/~/media/Site/guildhall/Documents/Theses/Delmer_Stephan_Thesis_Final.ashx?la=en