# Design of a Remote-Cockpit for small Aerospace Vehicles

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**Abstract:** Remote-cockpit is a new-generation avionics monitoring system that offers the control and visualization of all the avionics' data of remotely located small unmanned aerospace vehicles. It integrates all the features of a Ground station of an aerospace vehicle into a customizable avionics segment that can manage and control multiple aerospace vehicles. Our goal is to design a smart, Comprehensive, Full featured, Multi-touchscreen Remote-Cockpit which should be modular, Adaptive and extendable. This cockpit will function as the General cockpit to display and manage different parameters of multiple aerospace vehicles present at a distant location. In this paper we will present an approach of such kind of remote cockpit station for miniature aerospace vehicles.

## 1. INTRODUCTION

The Proposed Remote-Cockpit will provide a state-of-the-art generalized platform to the students and to the engineers within the field of Aerospace Technology to develop their own ground station software system that will satisfy the vehicle's mission objectives and also will provide hands-on learning experience for controlling and maneuvering real time aerospace applications. The Remote-Cockpit is designed around the concept of small scale aerospace vehicles, especially which are built in the chair of Aerospace Information Technology at the University of Wuerzburg. Our remote cockpit interface has 4 workplaces as shown in figure 1 and 2 with two interactive pilots' interfaces and two commanders' interfaces. All may enter commands using touch screen interfaces and receive telemetry data from the controlled vehicles, but only the pilots have the ability to control directly the vehicles.

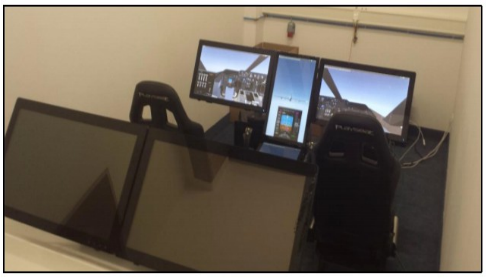
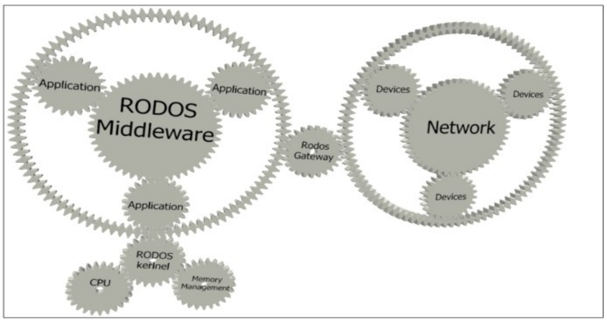


Figure 1: Panels for Remote Cockpit

Figure 2: Seating for the Pilot

## 2. SOFTWARE ARCHITECTURE OF THE CONTROLLED VEHICLES

All of the miniature vehicles will work under a specially developed real time and Object Oriented Dependable Operating System RODOS. RODOS has been ported on different development platforms that are being used on different applications. RODOS is jointly developed by the Central Core Avionics department at the German Aerospace Center and the Chair of Aerospace Information Technology at the University of Wuerzburg in Germany[1]. RODOS is specifically developed for aerospace applications as it has minimal footprint but it is also very well suited to all applications that demand high dependability. Software components in RODOS adjust each other to provide dependable computing [2] as shown in figure 3.



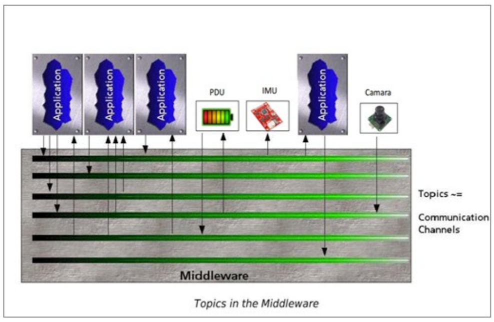




Figure 3: Structure of RODOS

Figure 4: RODOS Middleware

RODOS Kernel is controlling all the application on the vehicle through its threads. All the applications are developed with C++. RODOS is managing all the operations of the vehicles by its different layers. The bottom layer handles all the low level hardware management, Startups, Initialization etc. The Layer which contains RODOS kernel facilitates all the activities of the threads regarding the time and memory management [1]. Information exchange takes place among the components of the system through the RODOS middleware which uses the publisher-subscriber mechanism as shown in figure 4.

**3. RODOS-GATEWAY**

The data transmission and reception between the Aerospace Vehicles and the Remote-Cockpit can be achieved using any wireless communication module that can have serial, CAN or UDP interfaces. A communication channel with a station to transmit and receive data can be establishes as depicted in the figure 5 using the RODOS Gateway. In order to ease the process of developing a Ground station, a predefined protocol is being supplied inside a RODOS Wrapper for the development environment used to implement the ground station. This way the data can be transmitted and receive through the same data structure and its corresponding Topic ID and one don't have to care about separating the data bytes from its whole frame. RODOS wrapper can extract the data just on the basis of Topic ID of the message. Each expected message is listed in the code of the ground station with its data structure and corresponding Topic ID. The user only has to initiate the RODOS Gateway on the board side as well as on the Ground Station.

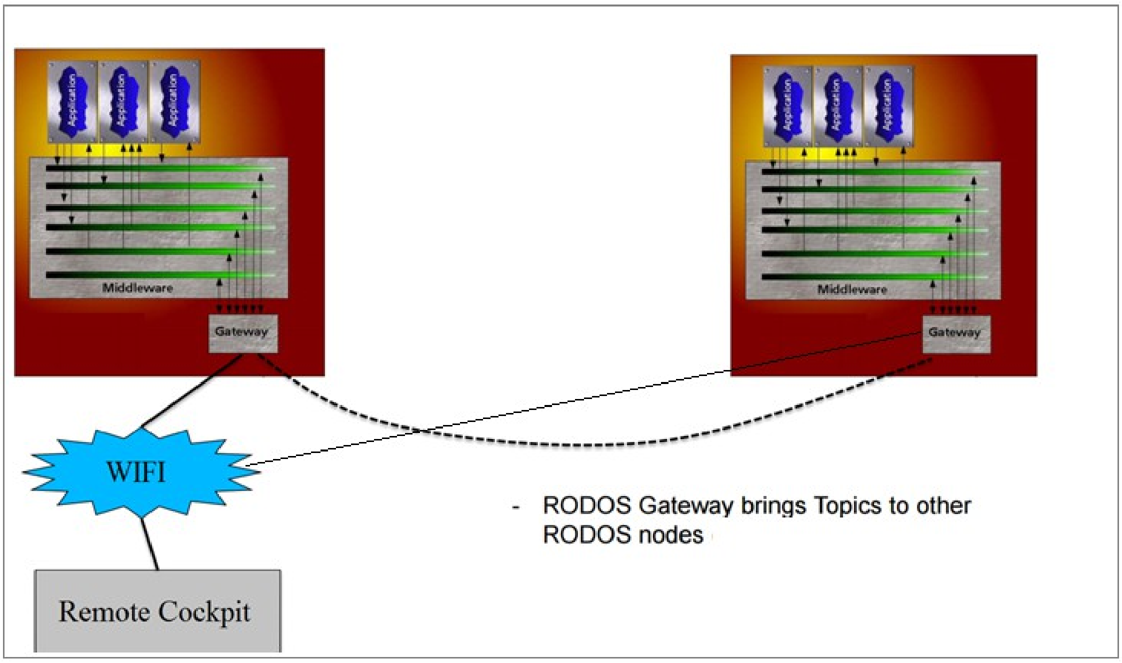



Figure 5: Communication b/w Multiple Aerospace Vehicles and Remote-Cockpit

## 4. THE REMOTE-COCKPIT CONCEPT

The Remote-cockpit consist of four distributed desktop computers, each one has two state-of-the-art touch screen monitors. Two of the computing nodes can control directly the vehicles in their different operation modes using two attached joysticks. There is also a projector display attached with one of the station which can be used to monitor the progress of the mission using live video streaming. The conceptual diagram of the system is shown in figure 6. The cockpit stations are wirelessly connected via WIFI network and can exchange information with each other using the RODOS Gateway protocol. The RODOS Gateway protocol gives a very robust and portable platform to enable the remote cockpit stations to connect easily to multiple computation nodes that are using different wireless communication modules like WIFI, Bluetooth, Ultra-Wideband or RF communication modules. The ground stations are developed normally using a C++ cross platform development tool like Qt. However any GUI building tool can also be used and connected easily through the RODOS gateway to the controlled vehicles.

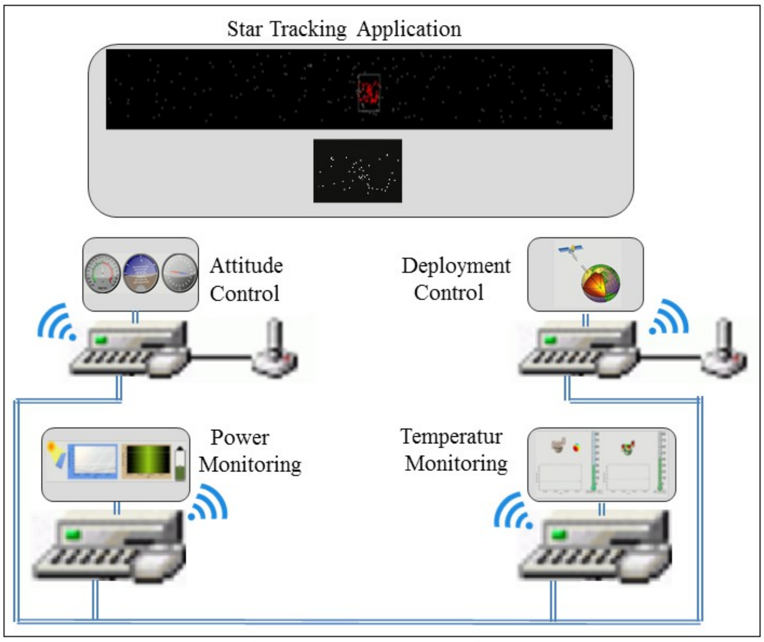



Figure 6: Conceptual Remote Cockpit Station

## 4. APPLICATIONS

### 4.1 ALINA

The Aerospace Information Technology department in University of Wuerzburg is developing the software for the first private moon mission ALINA, from Part time scientists (PTS)[3]. The project involves programming both the lander as well as rover on the moon as shown in figure 7 and 8.

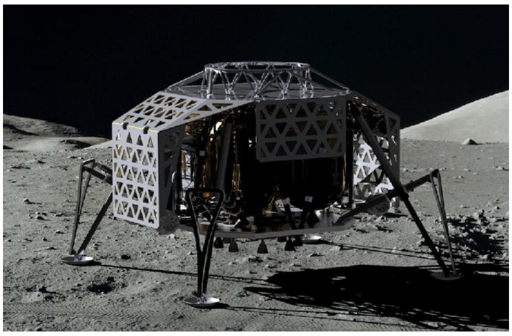


Figure 7: ALINA Lander

Figure 8: ALINA Rover

Our remote pilot interface will be used to monitor in real time the telemetry parameter of both the lander and the rover. The department will provide interfaces to monitor the flight to the moon beginning at low earth orbit (LEO) until the landing. After landing, it will be switched to rover control and monitor rover on its way to the moon. The mission and rover control will be performed in two mission control centers from PTS while our remote cockpit will stay in standby as second backup station where both can be commanded in real time (with a delay of 2 seconds) from our remote cockpit.

**4.2 Floating-Satellite (FloatSat) System**

The Chair of Aerospace Information Technology at the University of Wuerzburg (Germany) has developed a Floating Satellite (FloatSat) system in order to help students understand and get familiar with basic satellite subsystems and also to develop and test different attitude control algorithms and strategies for small satellites in an almost frictionless environment similar to that in space. This system has been used with excellent feedback by the postgraduate students as a compulsory course in the SpaceMaster program, as well as by the undergraduate students as part of the exercises offered in the Aerospace Laboratory [4].

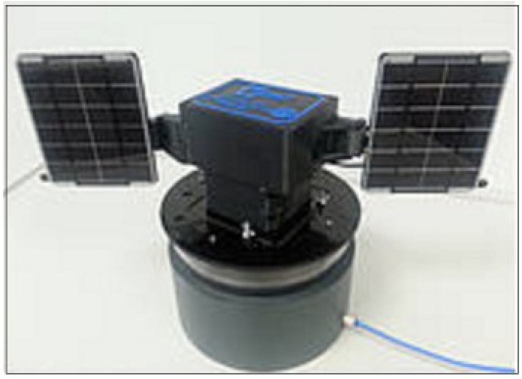


Figure 9: FloatSat System

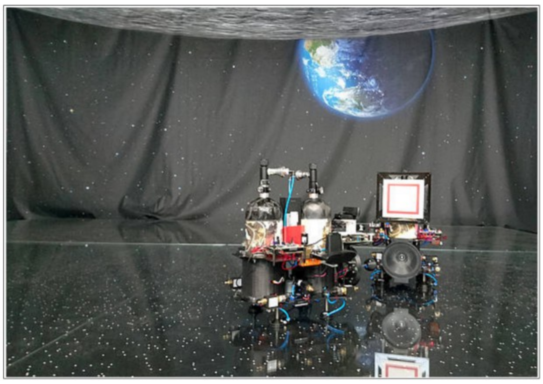


Figure 10: Space Maneuvering and Docking

The Floatsat system is consisted mainly from a mechanical structure that contains the basic satellite subsystems. This structure is placed into a hemisphere shell that it is floating inside a spherical air bearing unit. The air bearing unit requires compressed air as input whose pressure varies depending on the mass of the floating unit as shown in figure 9. In order to monitor and command the FloatSat, a ground station computer is required to communicate via the Bluetooth or the Wi-Fi module available in the satellite through commanding and telemetry display tool.

The FloatSat can be configured to satisfy different mission applications like deployment of solar panels, ejection and deployment of a solar sail, multi-satellite docking, space debris removal, monitor and track asteroids, 3D mapping of an unknown terrain on the surface of a planet or asteroid, star tracking system implementation etc. The students need to use the remote-cockpit to control the satellites and monitor its operational in order to complete the missions successfully. This will involve developing their own ground station software system using a common communication protocol based on RODOS Gateway.

### 4.3 Space Maneuvering and Docking Facility

The SMD facility is used to help researchers and students develop and test different control algorithms and strategies for space rendezvous, docking and formation flying in a frictionless, space-like environment. The SMD vehicle consists mainly of a mechanical structure, which is supported by flat circular air bearing pads which produces frictionless motion on a flat and smooth surface of glass plates for microgravity environment. The propulsion subsystem of the vehicle consists of compressed air supply tanks with proportional valves to control the flow rate and pressure release nozzles as actuators as shown in figure 10. A star tracker based position and attitude determination system is used to navigate the vehicles in the facility. The Remote-cockpit is used to steer and monitor the vehicles at the facility where several rendezvous and docking scenarios can be tested and verified.

## 5. EXPERIMENTAL RESULTS

The salient features of the Remote-Cockpit include real time operating system which smartly handles all the transmission, and an interactive display for the telemetry and telecommand information. Normally, an Aerospace Vehicles will have different modes of operation. Each computing node can run an independent graphical user interface that corresponds to the telemetry of the aerospace vehicle. While one monitor can display the power being consumed and the battery status and also the inner and outer temperature of the vehicle. The second monitor can show the information regarding the Attitude and Heading Reference System which informs the operator about the Pitch, Roll and Yaw of the controlled segment as shown in figure 11.


Figure 11: Graphical User Interface in Remote-Cockpit Station

### 5.1 3D-MAPPING OF AN UNKNOWN TERRAIN

A satellite mission of 3D mapping of an unknown terrain on the surface of a planet or asteroid was simulated with the FloatSat system using the Remote-Cockpit. In the Remote-Cockpit, the telemetry data of the satellite's rotational speed and orientation and the infrared proximity sensor measurements were used to construct a 3D-mapping of a scanned terrain. A scanning mechanism consisted of rotating the satellite with controlled constant rotation speed between two orientation points that cover the area needed to be mapped and moving the infrared sensor vertically using linear actuator mechanism was used to give a very accurate measurements that was transformed to form the resulting 3D geometry of the scanned area as shown in figure 12.

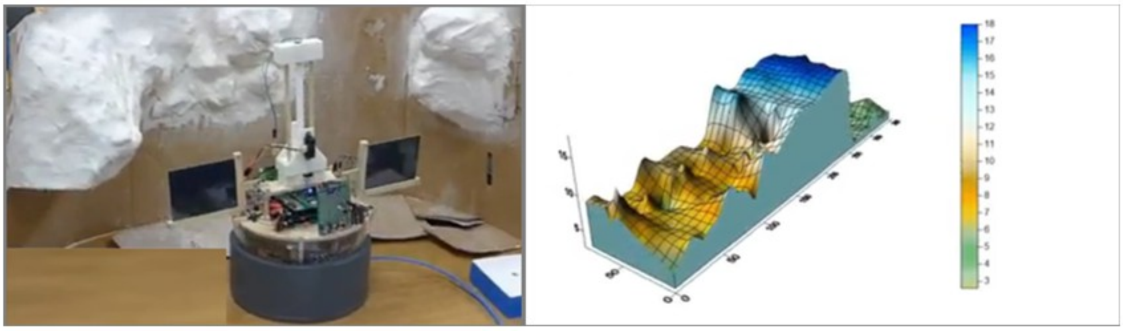


Figure 12: 3D-Mapping of Geometrical Surfaces.

**5.2 DOCKING OF FLOATING SATELLITE SYSTEMS.**

Manual docking mission between two Float-Sat systems to simulate real space docking missions was simulated successfully using the Remote-Cockpit. Multiple docking ports with attached electromagnets and with linear actuator mechanism to move the docking ports horizontally were used as displayed in figure 13.

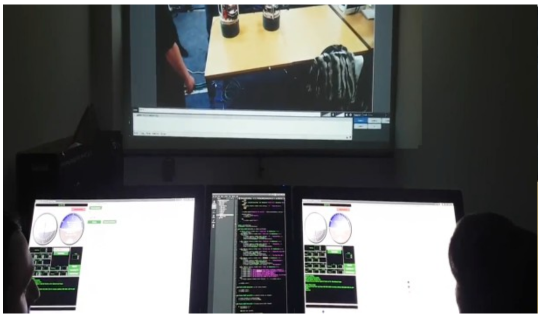


Figure 13: Float-Sats with Docking Ports

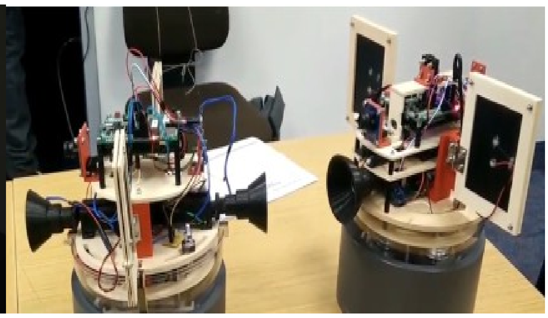


Figure 14: Docking Monitoring

Every satellite has one pilot and one commander. The pilot can control the orientation of his own satellite using the joystick and launch the docking mechanism. The commander normally observe the overall operation from his station and give the clearance for the pilot to dock with the other satellite after making sure that the docking ports of the satellites are in full alignment using the telemetry data and the camera feed that he receive from the satellite. The whole docking scenario is being live telecasted from the remote place where the Float-Sats are present to the cockpit station as shown in figures 14 and 15.

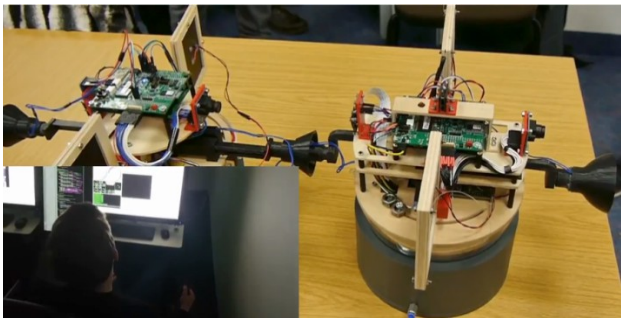


Figure 15: Manual Docking between two FloatSats.

## 6. CONCLUSION

The Remote-Cockpit is developed to facilitate the students in order to connect a remotely located aerospace device and control all its operation as the vehicle is present locally. In order to monitor and command the small satellites the Remote-Cockpit station will serve as a ground station which will communicate via wireless communication module with the remotely located satellite through commanding and telemetry display tool. It is a scalable approach which would be further enhanced and refined by the Aerospace students and researchers of our department by using the modern strategies of the Human-machine interface to display the spacecraft's sensor and actuator data and to supervise its integrity and regulate its operation. Other objective of the Remote-Cockpit project is to give the students and researchers a hands-on experience in working inside a mission control center for monitoring and controlling Aerospace Vehicles and furthermore it is intended to be used as a real mission control center for future missions.

## 7. REFERENCES

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