TIM - Telematic International Mission

A Regional Leaders´ Summit (RLS) supported space project

Newsletter 2020

The Telematics International Mission (TIM) is a multinational effort to combine multiple nanosatellite mission in a larger formation, aiming at different remote sensing applications. In TIM, institutes from around the world join by contributing with their own satellite formations and ground infrastructure. In TIM project, partners from the Regional Leader Summit (RLS) of partner states from 5 continents, cooperate under the technical leadership of Zentrum für Telematik e.V.

Editorial

The 2016 Regional Leaders Summit selected as one of their joint scientific projects TIM – the ***T***elematics ***I***nternational ***M***ission, a small satellite formation for Earth observation. TIM takes advantage that all RLS-partners have outstanding capabilities and expertise in space technologies. By combining them, challenging, innovative Earth observations with CubeSats are addressed. The TIM formation of cooperating small satellites extends joint RLS projects even to space, and enables acquisition of Earth observation data for improved monitoring of agriculture, emergencies and pollution. The partners started at different speeds, but the impressive 10th RLS-meeting at the Brazilian Space Agency INPE 2019 displayed in workshops and meetings the achieved progress and motivated the next steps. The partner contributions to space and ground segment of TIM were consolidated, leading to an envisaged launch of the satellites in 2021. We are now all very excited to see our initial ideas materializing in real space hardware.

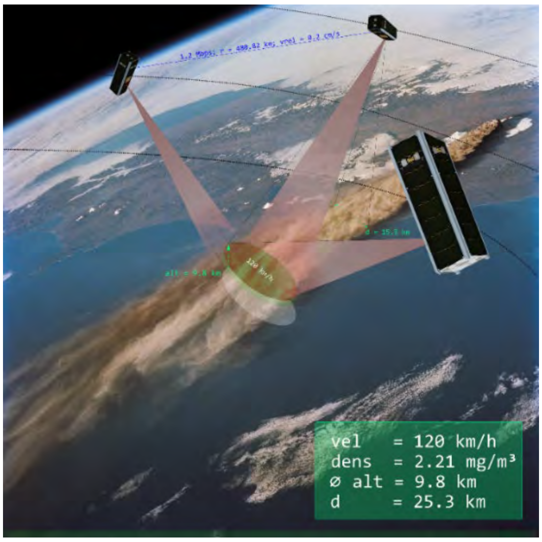

Figure 1 Artist's view of the TOM Formation combining joint observations from different perspectives to 3D images.

This newsletter intends to provide a survey of the current state of TIM at all partner sites, as well as to summarize the already achieved technology progress and to point out future application perspectives for this joint international RLS-effort.

Motivation

TIM will primarily focus on Earth observation using a nanosatellite formation. This enables observation of target areas on the Earth's surface from different perspectives. Three-dimensional surface maps can this way be generated by photogrammetric methods. The TIM formation, thereby, presents solutions to cutting edge problems such as the identification of sea vessels, monitoring thermal anomalies or 3D earth observation. The latter is particularly interesting for measuring the height of (ash) clouds, to determine their motion. The suggested concept will perform Cloud Top Height (CTH) as well as cloud ascent velocity using photogrammetry. The approach is shown to provide results with a resolution comparable to LIDAR.

Current Status and Latest Developments

During the last RLS Meeting, it was agreed to launch the first satellite formation in Q1 2021.

At the time of writing the Chinese partners from Shandong as well as the Bavarian partners from Würzburg will contribute a formation of three 3U Satellites each. The 6 Satellite formation will perform stereoscopic earth observation. The development of the Satellites is currently in progress. The additional RLS-partners will support the mission by components and development. Additionally further mission ideas exist. In order to support the satellite mission and use the benefit of the global coverage of partner institutes, a ground station network was established.

The following sections will first outline the ground station network before the individual RLS-Partner mission and the current state of development are covered.

The TIM Ground Station Network

International collaboration and technology exchange is a significant focal point for TIM as outlined above. With an aim to foster collaboration and resource sharing, TIM partners also envisaged a Ground Station Network (GSN) across RLS member states such that all satellites will have increased observability and ground resources will have lower downtime. Payload and telemetry data will also significantly increase benefitting all participating institutes. The first steps in the direction of establishing the GSN have been initiated in Würzburg. An Internet of Things (IoT) and web technology based concept has been proposed. The network will demostrate integration of heterogenous software and hardware as well as sophisticated scheduling algorithms. It will also support exchange of technical knowhow as well as possibilites of data fusion for Earth Observation. Partners in Shangdong, Brazil, South Africa, and Canada have already joined collaboration with information about their ground stations. Based on the latest information from partners, the various ground stations have been mapped in Figure 3, showing a good distribution in latitude and longitude. Soon, testing of the first iteration of the network will be initiated. The University of Würzburg with support from ZfT is coordinating the development and testing activities.

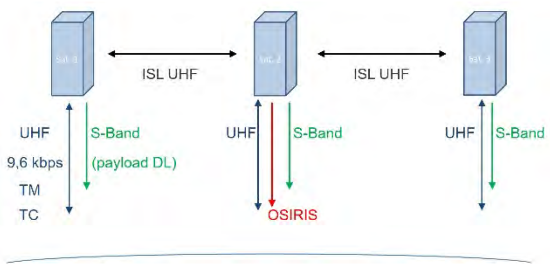

Figure 2 Communication channels in TIM

Figure 3 Ground Stations of the TIM Network

Relevant to the GSN is also the planned communication channels in TIM as depicted in Figure 2. The UHF Band is used for TT&C and low speed data transfer. The Inter-satellite link (ISL) will also operate in UHF. S-Band is used for high speed downlink of the payload data. Additionally, OSIRIS is an experimental optical downlink that is a used on the German TOM satellites for payload data downlink.

The Chinese Formation from Shandong

The TIM project is strongly supported by the Shandong Provincial Government of China, and has been established as a major scientific and technological innovation project in the Shandong Province, China. The Shandong Institute of Space Electronic Technology (SISET) in Yantai received funding from Shandong government to contribute 3 small satellites to the TIM project. The three cube satellites are named TIMS-A / B / C.

The Chinese satellites of the TIM will obtain general information about the ground area as well as altitude information, e.g. in case of severe disasters such as volcanoes and tsunamis. This will be achieved by observing the same target on the ground from different angles. This method can replace the traditional large-satellite ground measurements, with a comparable resolution. Through on-orbit operation of the TIM satellite, the feasibility of Structure From Motion (SFM) photogrammetry technology on small satellites will be shown and the achievable accuracies verified, which will play an important role in the future commercial application of the technology.

Design of the Chinese TIM-Satellites

The Chinese participation in the TIM project includes three satellites, the satellites are named TIMS-A/B/C. They are composed of identical hardware, adopting the standard 3U CubeSat structure (the envelope size of the satellite is 370mm x 130mm x 120mm). Each satellite weighs approximately 5 kg, and the satellite system design life is 1 year. The TIM satellite system is composed of a satellite platform and payload system. The satellite platform includes the structure and thermal control subsystem, integrated electronic sub-system, power subsystem, measurement and transmission subsystem, attitude control sub-system and propulsion subsystem. The payload is a visible light camera to achieve ground imaging. The basic block diagram of the sa-tellite system is shown in Figure 4.

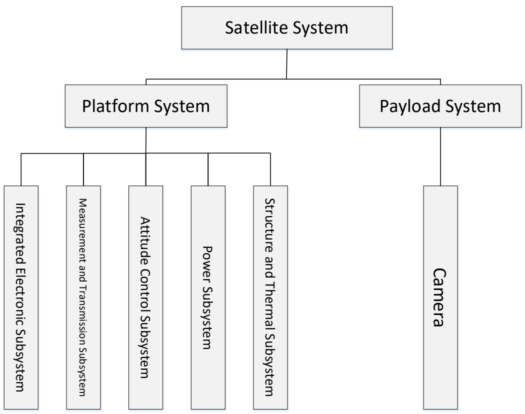

Figure 4 System overview of the Chinese TIM satellite

The integrated electronic subsystem includes the central computer and navigation system. It is the key part for the satellite's reliability and lifetime. The satellite measurement and transmission subsystem is composed of UV-satellite-ground measurement and control device, UHF inter-satellite measurement and control device, and X-band data transmission device. The attitude control subsystem consists of attitude measurement devices, attitude control devices and attitude control algorithm. The propulsion subsystem uses micro-cathode arc thruster, which has the advantages of small size, high specific impulse and large thrust, which can meet the requirements of the TIM formation. The Chinese TIM satellites adopt the standard 3U CubeSat structure & design, and use the 3U cube standard ejection mechanism to separate from the launch vehicle. The basic configuration of the satellite is shown in Figure 5.

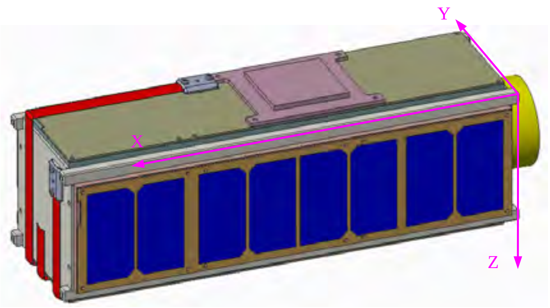

Figure 5 Configuration of Satellite

The satellite structure is divided into three main areas according to function, as displayed in Figure 6. The first is the payload compartment, including the camera and electric propulsion unit. The second area is the electronics stack, including the satellite's integrated electronic subsystem, the measurement and transmission subsystem, and the power subsystem. The third area is the attitude control component and includes gyro, reaction wheels, sun sensors and magnetorquer.

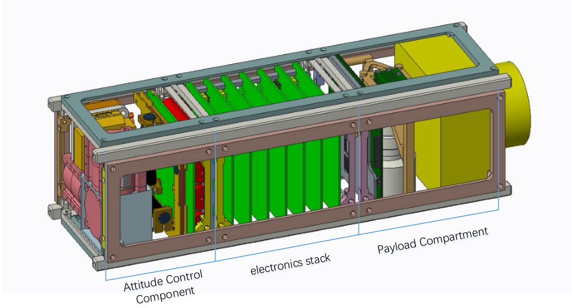

Figure 6 Three main areas of satellite

Contact Person:

Zhang Zhongzheng
zhangzhongzheng@live.cn

The Bavarian TOM-Formation from Germany

The state of Bavaria sponsors the 3 formation flying small satellites of the Telematics earth Observation Mission (TOM), which is developed at the ZfT in cooperation with the University of Würzburg. TOM follows on the steps of NetSat and the UWE satellite family developed previously at Zft and the University of Würzburg, respectively. In TOM three nano-satellites carrying cameras in the visible range track and perform simultaneous measurements from different perspectives of the same target on the surface of the Earth. These observations form the basis to apply photogrammetric approaches for sensor data fusion to generate three-dimensional images of the target area (the concept is outlined in Figure 8). The satellite platform will be based on a 3U-

Figure 7 Mission Badge of the Telematics earth Observation Mission (TOM)

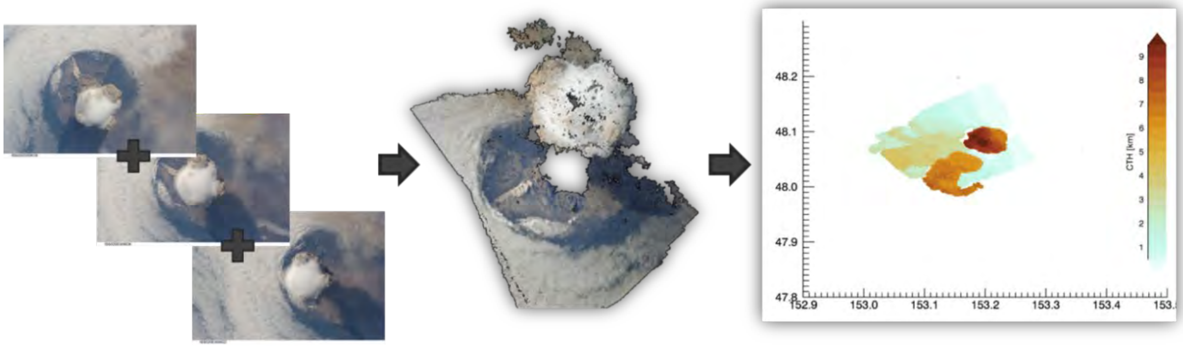

Figure 8 Multiple Pictures taken from different angles are processed to a 3d image, which can be used for CTH analysis

Cubesat design that extends the modular design that was already successfully demonstrated on UWE-3, allowing for quick and flexible integration. This concept has been elaborated into an electrical interface standard and is promoted by UNISEC Europe[1], and will be supported in TIM-satellites in order to provide compatibility of components and subsystems between the partners. The standard is optimized for rapid integration and testing, thus reducing development time frame.

TOM-Satellite Design

The preliminary pico-satellite system design of the TOM Satellite is shown in Figure 11. The Satellites will be built in 3U configuration. The main payload will be an optical sensor. Most likely the SCS Gecko Imager. The communication is split in UHF, which will be used for TT&C as well as ISL and the payload data downlink in S-Band (MHz). The communication

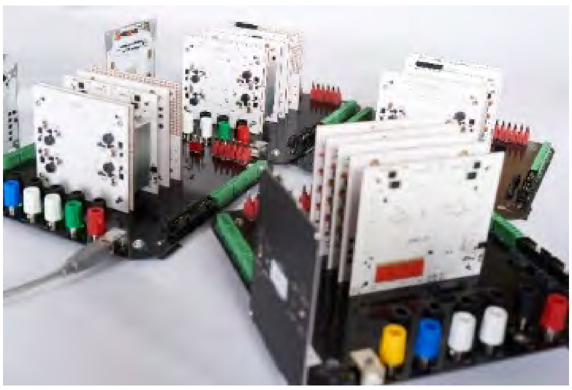

Figure 10 Flat-Sat Setup for easy Test & Development of Satellite Subsystems

module for UHF is GomSpace's NanoCom AX100[2], which offers Ax25 support. The transmitter for S-Band will be provided by Iq-Spacecom's Hispico transceiver[3]. This provides a payload data rate of up to 1.6Mbps. It requires a specific receiver for ground stations.

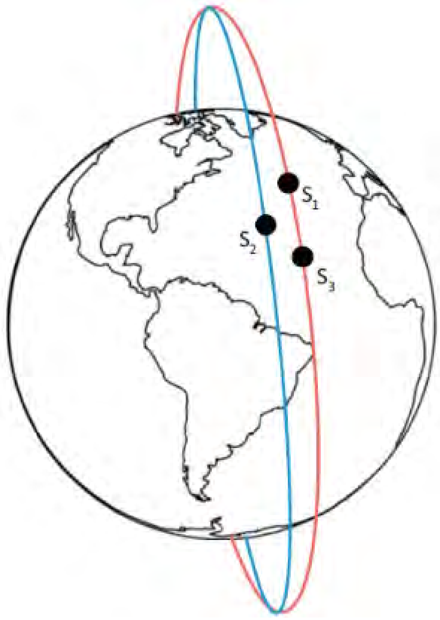

Figure 9 Orbit design of the TOM Formation

Additionally, one of the TOM satellites houses an optical link to the ground, demonstrating the capability of a high-bandwidth. One of the main challenges of TOM is the formation flying technologies for the coordination of the three TOM satellites to perform joint observations. The technology base focusses on networked

[1] http://unisec-europe.eu/standards/bus/
[2] https://gomspace.com/shop/subsystems/communication-systems/nanocom-ax100.aspx
[3] https://www.iq-spacecom.com/products/hispico

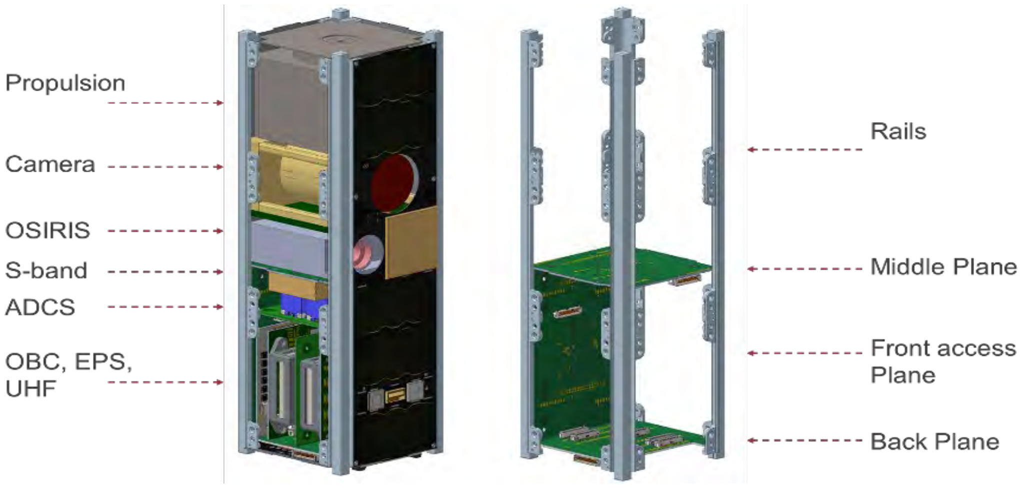

Figure 11 preliminary TOM Satellite Design

control algorithms, using inter-satellite links and relative navigation approaches. In this context particularly challenging is the attitude and orbit control system at the size of a 3U-CubeSat to realize appropriate pointing accuracy. For this purpose, miniature reaction wheels have been developed with specific high rotation speed as essential element of the attitude control system. The propulsion system used in TOM is the IFM NANO thruster by Enpulsion[4]. They are currently tested in one of ZfT's other missions. A Flat-Sat setup is shown in Figure 10.

Orbit & Formation design for TOM

In order to meet the project goals of achieving a comparable performance to Lidar by photogrammetric measurements, it is necessary to achieve a vertical precision of ca 200m. However, TOM aims to provide results with 20m precision, which make possible to measure also the vertical speed of the clouds. In accordance with the above requirements, the following orbit design was done: The three TOM satellites form a triple pendulum formation with a baseline of ca 100km. The out of plane separation is about 50km in order to improve the coherence of the imagery data. The quality of results depends mainly on the ratio between baseline and satellite altitude. Such triangle formation provides more stable results than a string of pearls in across track direction.

Visual servoing

An additional goal of TOM is the demonstration of a novel method for improving satellite attitude control by visual servoing, which calculates features of camera images on-board. This also serves as input precision for fine pointing of the control systems. The formation will consist of at least 3 German TOM satellites. One of the satellites will be configured as the master. Its task is to detect, describe and continuously track features. It will also transmit this information in form of descriptors to the slave satellites. After receiving the descriptors, they will detect and describe the features as well. Then a matching between Slave and Master Descriptors is performed. And the matched features are tracked by the slave satellites as well. The Procedure is outlined in Figure 13.

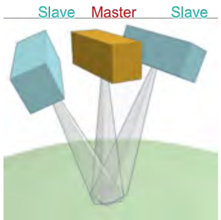

Figure 12 Satellite Formation for Visual Servoing

Contact Persons:

Prof. Dr. Klaus Schilling
klaus.schilling@telematik-zentrum.de
Alexander Kleinschrodt
alexander.kleinschrodt@telematik-zentrum.de

[4] https://www.enpulsion.com/

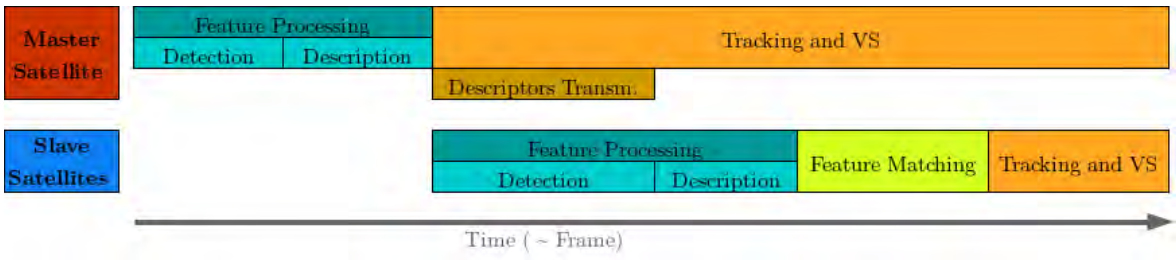

Figure 13 Visual Servoing tasks of Master and Slave Satellites

The Assembly Integration and Test (AIT) in São Paulo, Brazil

The test centre LIT (Laboratory of Integration and Testing), in São José dos Campos, is part of the Brazilian Institute for Space Research (INPE) and hosts impressive facilities for functional and environmental satellite tests. In 2019 INPE hosted the 10th RLS Meeting, during which the TIM project meeting took place. LIT can be used for Assembly, Integration, and Testing (AIT) of nanosatellites and it offers support and engineering consulting for the elaboration of the AIT plan. Mass and physical measurements can be performed, which e.g. is important for precise attitude control. Cleanrooms (ISO 7 and ISO 8) are also available for assembly and integration. Further test facilities include: thermal and thermal-vacuum tests; dynamic tests; electromagnetic compatibility tests. LIT also offers support in logistic and operation for these different activities. As a contribution from the São Paulo region mission to TIM and the Small Satellites-RLS, the group at the Laboratory of Concurrent System Engineering (LSIS) from LIT began in 2019 two conceptual missions studies, based on the needs of the Meteorology (CPTEC) and Earth Observation (OBT) areas from INPE. The first proposed mission is a Brazilian Constellation for Eart-Observation, able to work jointly with CBERS 4, CBERS 4A, and Amazônia -1 (Brazilian satellites) data. It aims to support the identification of rain forest fires with more accuracy and to avoid false alerts. The constellation would provide several advantages, mainly the availability of images with high temporal and spatial resolution, in the Brazilian Amazon region. A preliminary analysis was carried out to establish the main mission requirements, including the need for a constellation of at least four nanosatellites, using active attitude control to change the imaging targets. The second proposed mission applied to the meteorological area consists of cloud-forming observation mainly present in the tropics. A satellite formation was proposed for collecting data to estimate the vertical velocity of clouds. These experimental data are necessary to improve existing numerical models from CPTEC, and weather forecast. These conceptual missions could be a contribution to future Small Satellites-RLS projects.

Contact Person:

Prof. Dr. Geilson Loureiro
geilson@lit.inpe.br

Image data processing -Quebec, Canada

The team in Quebec will provide support in two areas: (1) Offline data processing: once the data are received through the network of ground stations, they need to be analysed for 3D reconstruction and to extract relevant infor-

Figure 14 The student team at Polytechnique with the Ground Station Antenna

mation. The team at CRIM and at Polytechnique have long experience in the processing of large-scale geometric data and will use recent algorithms and the resources of CalculQuebec to perform the data analysis. The results will be shared with the rest of the team. (2) The team at Polytechnique has developed visual-based coordination strategies for multi-robot cartography. These strategies can be applied to provide masterless visual servoing, with peer-to-peer communication and collective decision making for a group of satellites. The team will therefore assist in the software development and testing for the visual servoing part of the project. The team is also in talks with a company to start a local research project for the use of decentralized control for multi-satellite systems. The company would provide a visually accurate 3D simulator that can be used to validate visual servoing, communication, and coordination strategies. The collaboration with a local company would open the doors for the team to acquire much needed additional funding, as it is a requirement from both federal and provincial agencies to have a minimum of 20% cash contribution from industry for most funding opportunities. Another substantial funding opportunity is available from the federal government (the Alliance program). The team will apply, but the acceptance rate for the program is expected to be very low. In Québec the project has been discussed in several occasions, and Québec has hosted the 2018 TIM project meeting. Quebec has funding for one satellite without payload and launch. Furthermore the Quebec will support TIM with their Ground station as soon as it is installed and functional.

Contact Person:

Dr. Giovanni Beltrame
giovanni.beltrame@polymtl.ca

Ground Station Support from Western Cape, South Africa

South Africa did not receive any government support, despite the innovative satellite mission they wanted to realise in the frame of TIM. However Stellenbosch University will still contribute with support via Ground Station.

Contacts Persons:

Prof.Dr.Herman Steyn
whsteyn@sun.ac.za
Prof.Dr.Robert van Zyl
vanzylr@cput.ac.za

Figure 15 Ground Station at the Western Cape, South Africa

Project Timeline

The official Launch Date for the TIM Formation was agreed to be in Q1 2021. This will probably mean that not every partner can participate with an own implementation of a satellite system. Local government requires us to finish the already started project in timely matter. Still cooperation and involvement of all RLS-partners is done, e.g. by the actions outlined in the following: 1) by sharing developments: e.g., sharing of components has been a huge part of the project from the beginning, the joint UNISEC bus enables the easy swapping of components. 2) Providing access to testing and building facilities for testing, integration as well as qualification. 3) Most important is the support of the Mission by joining the individual partner's ground station to the TIM network.

Future Perspectives

The next technology step following TIM will be application of more elaborated data fusion and formation flying techniques to Earth observation. Thus, on basis of TIM technologies the highly reputed ERC Synergy Grant "CloudCT" was awarded to the Israeli-German team of the professors Schechner, Koren and Schilling in 2018, to characterize the interior of clouds by generating 3D-images.

Meetings

Meetings take place regularly during Regional Leaders Summits in partner countries.

- In 2016, TIM has been presented at the 8th RLS conference in Munich, Bavaria.
- In 2017, a dedicated TIM meeting was organized in Würzburg, Bavaria.
- In 2018 during the 9th RLS in Quebec-City
- In 2019 during the 10th RLS in São Paulo, Brazil

Figure 16 Impressions from the RLS-Meeting'19 in INPE, Sao Paulo, Brasil

The next RLS meeting in 2020 was scheduled to take place in Linz, Austria. Due to the recent pandemic this will be shifted to 2021. However as a replacement this year's meeting will be held virtually. For more up-to-date information, please consult the RLS-Sciences website: https://www.rls-sciences.org/

Further Information

Further information about the Small Satellites project within RLS-Sciences can be found on the TIM website: https://www.rls-sciences.org/small-satellites.html

The Project website can be found on: https://rls-smallsatellites.org/

The Zentrum für Telematik e.V. maintains an additional page at: https://www.telematik-zentrum.de/tom