



ICARUS

INVITATION TO JOIN A GLOBAL SMALL-OBJECT
(ANIMAL) OBSERVATION NETWORK



MAX-PLANCK-GESELLSCHAFT



What is ICARUS?

ICARUS, short for „International Cooperation for Animal Research Using Space“ is a global collaboration of animal scientists to establish a novel satellite based infrastructure for earth observation of small objects such as migratory birds, bats or sea turtles. ICARUS is a German-Russian cooperation program.

Why ICARUS?

ICARUS will provide a seeing-eye dog for humans by linking the evolved senses of animals in a living remote sensing network. Expected outcomes are:

- Discovery of unknown migrations
- Monitoring of global change (habitat shifts, desertification, glacial melts)
- Understanding ecosystem services (pollination, pest control, seed dispersal)
- Safeguarding global health (avian influenza, foot and mouth disease, ebola)
- Prevention of wildlife and forest crime
- Aiding global conservation (mapping causes of death in endangered species)

Possible additional outcomes are:

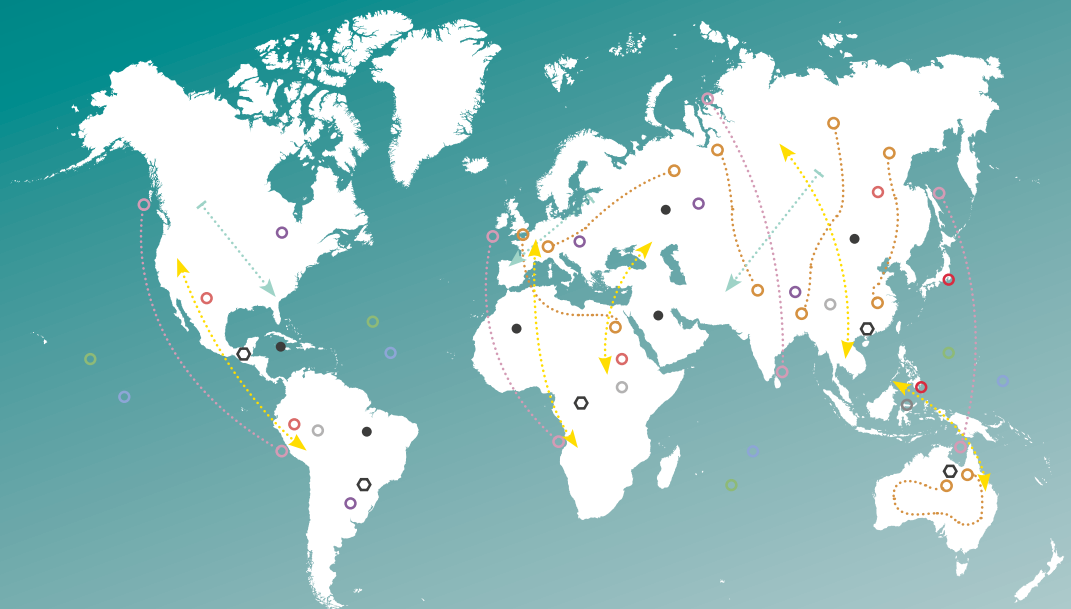
- Disaster forecast via animals (collective behavior of animals may predict flooding, volcanic eruptions, earthquakes)

How does ICARUS work?

- Data collection in logger tag on individual small animals including GPS, 3D acceleration sensors, magnetometer, temperature and other sensors
- Autonomous energy supply (solar cell in combination with rechargeable batteries)
- On-tag processing, data reduction and selection of relevant data
- Transmission of small data packages to LEO satellite (Low Earth Orbit)
- CDMA coding of signal and data
- Decoding of signal on board of satellite, downlink to ground station
- Data distribution and storage via Movebank (www.movebank.org)

Projects

- Seabirds
- Carnivores
- ↗ Navigation
- Shorebirds
- Waterbirds
- ↘ Cuckoos
- Seaturtles
- Thrushes
- Unknown migrations
- Bats
- Disaster
- Global Carbon Balance



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New Science and Technologies for a Globalized Planet

Sharing planet earth as a common habitat, the well-being of humans is directly connected to the existence of animals, be it as a source of food, the origin and carrier of diseases, or as an early warning system for human impacts on nature. Around the globe, billions of animals are roaming wildly all the time. They connect the most remote places on earth and in the oceans, and could be our sensors, our eyes, ears and noses for the health of our planet.

However, we poorly understand the biology of most wild animals because we cannot track their locations, internal and external conditions, their behavior, and most importantly, the reasons for their death. And yet, we need to know where, why and when animals are in trouble to preserve essential ecosystem services and to safeguard our own human livelihoods. The ICARUS Initiative (International Cooperation for Animal Research Using Space), a research endeavour that transcends disciplines and continents, will close this knowledge gap by monitoring the local, regional and global movement patterns of tagged animals.

Technical challenges:

- Global tag coverage to record long distance migration patterns
- Simultaneous communication with a multitude of animal tags
- Extremely low tag mass and size to allow tracking of small animals
- Long, maintenance-free tag life in order to cover complete migration cycles
- Logging of internal (physiological) & external (environmental) state of animals





System Overview

ICARUS consists of space-borne and ground-deployed elements. The space-borne elements are used as relay for the radio frequency communication link between animal tags and the Operations Center. The International Space Station (ISS) will be used as a first platform for the space-borne elements for the initial ICARUS demonstrator mission.

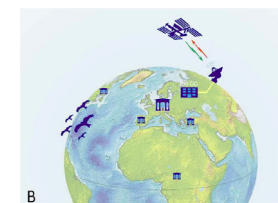
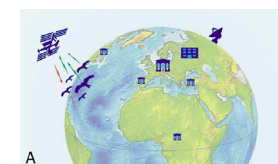
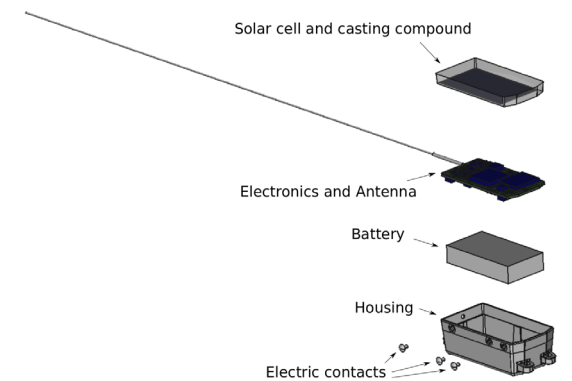
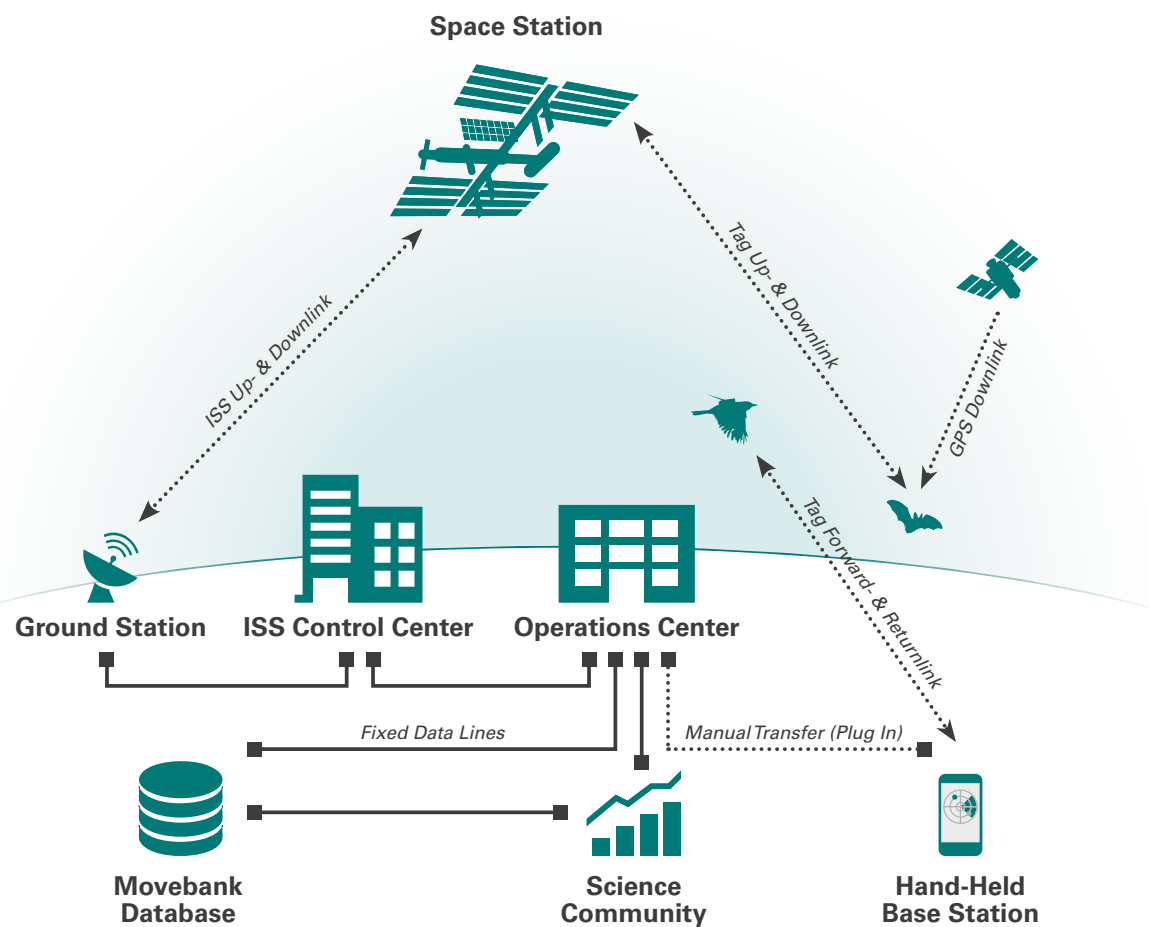
For the tags a two-way communication via RF link to the ISS is provided. The miniaturized tag attached to the animal is determining its position using GPS, thus providing the capability of logging the track of the tag with high accuracy. During contact with the ISS the tag transmits the recorded data and can receive reconfiguration commands. The Operations Center is monitoring and controlling the space-borne elements at the ISS and the tags via the ISS. In addition it is responsible for processing the science data and for disseminating them to the science community via the Movebank database. As amendment to the space link, the user can communicate with the tags at short range using hand-held base stations.



Animal Tag

The main challenge of ICARUS is the implementation of a low-volume data link between the tags on the animal and the transmitter-receiver on the ISS. A miniaturized animal tag provides the capability of communicating up to 800 km with the ICARUS equipment at the ISS, to measure its absolute position in regular intervals using GPS and to acquire local temperatures, acceleration and magnetometer values that give indications of the behavior of the animal – all with a mass of the tag less than 5 grams and a volume of approximately 2 cm³. To achieve this challenging objective, the essential functions of the tag are concentrated within miniaturized electronic units that are optimized for low power consumption, the main power consumers being the radio frequency communication system and the GPS. The design life time of the tag is at least one year.

Mass	< 5g	Battery capacity	70 mAh
Volume	approx. 2cm ³	Solar cells area	2 cm ²
Antenna Length	150 mm	Transmit power	approx. 6mW
Sensors	GPS		
	Accelerometer		
	Temperature		
	Magnetometer		



Communication Concept

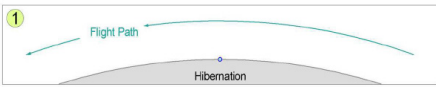

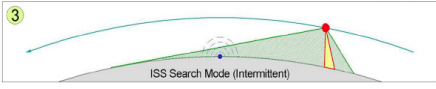
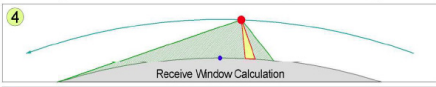
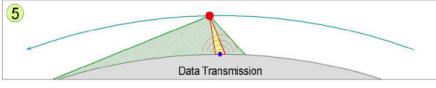
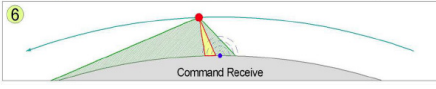
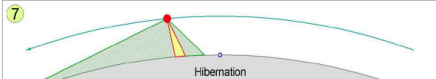
As soon as a tag is within the reception range of the ISS, it starts a communication sequence with listening to the downlink data stream and sending own position and sensor data gathered since the last contact (A).

The ICARUS on-board system at the ISS stores these data and transmits them during the next contact to the ISS ground station network. The raw data are forwarded to the ICARUS Operation Center, processed and stored in the scientific database (B).

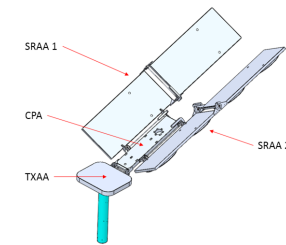
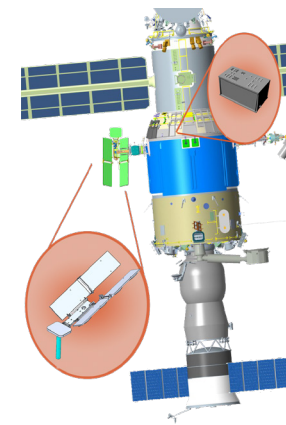
The scientists evaluate the data and may request a commanding of the tag at the ICARUS Operation Center in case an adjustment of configuration settings of the tag becomes necessary (C).

The command is transmitted to the ICARUS on-board equipment at the ISS (B). Next time the tag transmits new data and thereby registers at the Operations Center, the stored command for this tag is downlinked to the dedicated tag (A).

The communication sequence between tag and the ICARUS on-board equipment at the ISS consists of the following steps:

- Step 1:** The tag is in the hibernation mode, i.e. in the mode with the lowest power consumption, waiting for the internal timer to awake the system to life at the time of the expected ISS appearance.
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- Step 2:** After wake-up, the receiver starts listening intermittently in order to detect the presence of the ISS downlink radio frequency signal.
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- Step 3:** This intermittent operation will be continued until the detection is successful. With the successful reception of the ISS downlink signal, the tag will extract the most recent information about the ISS orbit from the received signal.
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- Step 4:** With the received ISS orbit data the tag will determine its relative position to the ISS using its own GPS based position on the ground. Based on this information the tag calculates its presence within the field of view of the ISS receive antennas. Until then the receiver will go back into stand-by mode.
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- Step 5:** Upon reaching the predicted receive window the tag will transmit the stored position and sensor data.
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- Step 6:** After data transmission, the tag will remain in receive mode for a predefined time to listen for a configuration command that may be sent by the ICARUS on-board equipment.
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- Step 7:** Before falling back into hibernation mode, the tag calculates the time gap until the next scheduled ISS contact. The hibernation mode is interrupted periodically for position determination and acquisition of sensor data.
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ICARUS Demonstrator Mission on the International Space Station (ISS)



The ICARUS on-board equipment has been accommodated on the Russian Segment of the ISS and will be in operative mode in 2018. It consists of an electronic unit, an antenna assembly with three receive antenna beams and a transmit antenna. The antennas are oriented such that they create on ground a transmit coverage forward and a reception area slightly backwards. The electronic unit will be installed inside the pressurized compartment. This unit is equipped with powerful processing capability to detect and distinguish the weak signals of up to 100 tags at the same time that are in the reception area of one of the three receive antennas.

Uplink (receive)		Receive antenna	
Frequency	401 – 406 MHz	Type	Patch antenna (SAP)
Bandwidth	1.5 MHz	2 Side antennas (SRAA1 and 2)	4 patches
Data rate (net)	520 bps	Dimensions (each side)	approx. 500 mm x 2000 mm
Data transmitted per ISS pass	1.784 bits	Centre antenna (CPA)	Electrically beam forming using the side antennas
Tag channel access method	CDMA		
Uplink Antenna footprint	30 km x 800 km		
Downlink (transmit)		Transmit antenna (TXAA)	
Frequency	467,5 – 469,5 MHz	Dimension	approx. 400 x 400 x 1200 mm ³
Bandwidth	50 kHz		
Data rate (net)	656 bps		
Downlink Antenna footprint	Diameter 1300 km		

Partner



The ISS is flying on a nearly circular orbit with a mean altitude of 400 - 460 km at an inclination of 51.6°. Within one day the ISS is orbiting the earth 16 times, each ground track shifted to the former one by approximately 2.500 km to the West. The ground pattern of the ICARUS on-board antennas covers in 24 hours more than 90 % of the earth between 56° Northern and Southern latitudes, with the longest revisit time close to the equator and short repetition cycles close to the higher latitudes. Because most of the land surface of the earth is in the northern hemisphere at higher latitudes, these conditions provide good read-out cycles for the ICARUS tags. Once validated, the developed low power communication system with a space-borne transponder and multiple miniaturized transceivers on earth paves the way for a multitude of other applications to the benefit of humankind, especially on a long time perspective with an extension of the in-orbit infrastructure by dedicated satellites that will lead to a shortening of revisit periods.

Invitation towards a global space partnership

- ICARUS will fly experimentally on the ISS
- Space nations as major partners are welcome to join ICARUS
- Major partners will:
 - Fly ICARUS payloads on their LEO satellite (Low Earth Orbit)
 - Receive technology transfer within the ICARUS team
 - Be able to build their own ground segment for the satellites, tags and do own research and observations
- Share joint data with all ICARUS partners
- Read out data for all other major partners thus receive better global coverage
- Partners are also welcome to share newest DLR-funded satellite bus technologies
- Pre-order ICARUS tags for your research





PLEASE JOIN US

WE NEED YOUR HELP AND EXPERTISE TO MAXIMIZE THE BENEFITS OF THIS GLOBAL SMALL-OBJECT (ANIMAL) OBSERVATION SYSTEM.

→ www.icarusinitiative.org

