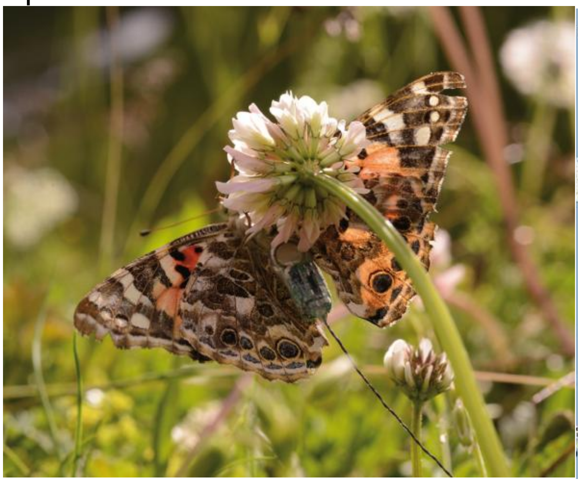
Biotelemetry

Migration of Animals

Scientists are studying the annual migration of animal herds, flocks of birds or insects to have a better understanding of the distribution of animals and their migratory habits – not least in the light of biological threats and pandemic diseases. The research project ICARUS will soon record animal movement via the International Space station ISS.



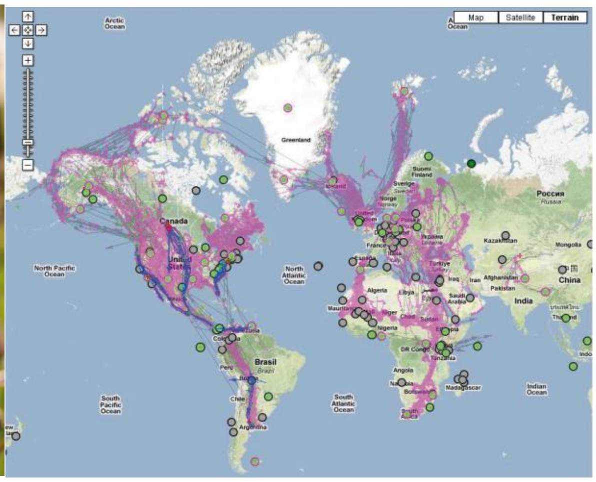


Fig.1: Screen shot of the database „Movebank" (www.movebank.org) with migration routes worldwide. Only a few migration routes of large species are known, many areas in the world are still "white patches". Only large birds can be watched via ARGOS satellite transmitters worldwide. Small animals like butterflies can only be equipped with a 0.2 gr transmitter and radio-tracked by hand (on foot, car, plane).

Migration behavior of animals

Animals are among the most important features of our planet and the vast majority are continuously on the move. Details of their migration routes are only known of a few species. How do they find their way? How much stress are they under? What are the effects, positive and negative, of their migration and their behavior on our shared habitat?

At present our understanding of the impacts of such things like natural hazards and –recently- human influence on animal migration is limited. Most often we do not know how these impacts might lead to extinction. As long as it is unclear where, when, how and why a single animal of a population dies, it cannot be understood how animals adapt to continuously changing environmental conditions. A dramatic example are the 10 billion of 20 billion migratory birds which die each year without us predicting their fate or being able to observe them.

Animals and us

Animals play an essential role for us humans and our habitat. Their behavioral changes are serving us as sensors and early indicators, because animals are affected by human actions.
Animals play an increasingly important role as disease carrier and source of epidemics. About 70% of the worldwide epidemic diseases, like SARS, the West Nile Virus or bird flu, result from zoonoses (from animal to human or from human to animal transmitted infectious diseases) in the interplay between wildlife, livestock and humans.

The reason for our limited knowledge is primarily a result of the fact that most animal species are relatively small, shy and speedy and can adapt well to their surroundings, thus evading our observations. Today we can track and observe small animals only in local areas, if we equip them with micro transmitters (fig.1, butterfly), and locate them via a radio beacon.

In regional areas mobile phone networks with their localization and transfer options are used. Unfortunately these transmission modules are too heavy for small species. For the study of global migration of wildlife satellite systems are needed, in which a PTT (Platform Terminal Transmitter) transmits its parameters and the location of the animal with minimal transmission power via satellite transponder to its observers.

Animal tracking with the help of satellites

For bigger animals the so called ARGOS systems (Advanced Research and Global Observation Satellite) enables observation of global animal migration for 20 years now. It was originally realized in the 1970s by the French space agency CNES for the needs of meteorology. Initially the system was almost exclusively intended for data transmission of data collecting platforms in meteorology. The platforms were scattered around remote locations on the globe and equipped with small automatically working transmitters, which transmitted local meteorological data like pressure, temperature, humidity and wind to the weather satellite as soon as radio communication was possible. The ARGOS system was later expanded for animal tracking. However, any additional advancement in ARGOS is necessarily difficult and long-winded, because the satellite type on which ARGOS-transponder-payload flies on, are operational weather satellites.
These must have a life expectancy of 10 to15 years, therefore every renewal on the astronautic side can be done earliest then. Moreover, with an operational working system every renewal in the overall system (satellite and animal) has to be backward compatible. In contrast, significant advancements in terrestrial mobile communication systems are made biennially as a result of the technological progress made in microelectronics. This is not feasible with ARGOS.

Therefore the research project ICARUS, which is still in its concept phase, was proposed. Using the International Space station ISS, new communication concepts will be develop and tested, which will allow a speedy implementation of technical advances without the above mentioned constraint. This project shall give scientists the possibility in the next six to eight years to immediately build and test up-to-date scientific instruments. Nevertheless, global data transmission of micro transmitters is a huge technical challenge.

Signal transmission over long distances

One of these difficulties is the radio contact between the transmitter, which is attached to the animal, and the satellite (the so called ‘Up-link’). The higher the satellite gets, the weaker is the signal, which it receives. The micro transmitter of the animal must radiate almost all of the upper half space, because the location of the animal can vary not only at flight, but also on the ground if wounded or dead. The satellite antenna on the other hand can have a preferred direction towards earth and a larger (for example one square meter) absorption area.
But even then the satellite will only receive 10^{-14} fractional amount of the transmitting power, if the inclined distance is 1000 km.
Further undesirable effects, like multipath effects or rain, can additionally cause signal weakening. The frequency selection of the transmission is determined by various factors. So far the preferred range is around 400 MHz. However, because of the worldwide regulations issued by regulatory authorities, this is not definitely fixed.

Besides a very small transmission power of the micro transmitter, which at maximum should have 50 milliwatt, the Up-link has another critical problem. All transmitters which are located at the current reception area of the satellite transponder may transmit uncoordinated. Such a situation is problematic because the position of the animals which have transmitters can be situated far apart – in extreme cases around 5000 km – or also very close together. Therefore, the signal mixture received at the satellite can vary in its performance and its Doppler shift, as explained below.

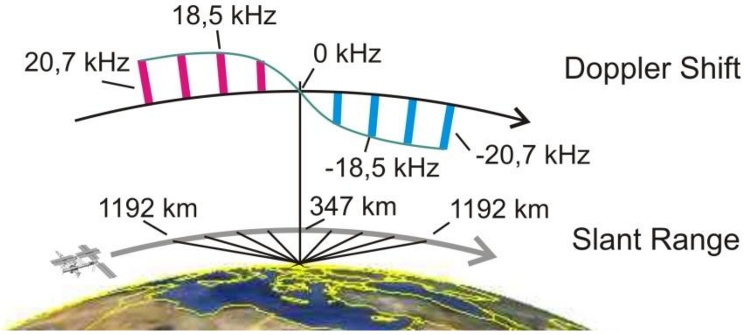


Fig.2: Doppler frequency displacements in communication between transmitter and satellite.

Doppler frequency displacements

If two objects, in our case animal and satellite, move relative to one another (hence moving towards or away from each other), the satellite receives a so called Doppler frequency-shifted signal. Therefore the frequency changes itself constantly (fig. 2). This effect, which is also called Doppler frequency shift, you can hear for example when a fire engine with siren goes past. Only where both objects are nearest to one another, the frequency offset is 0 Hz.

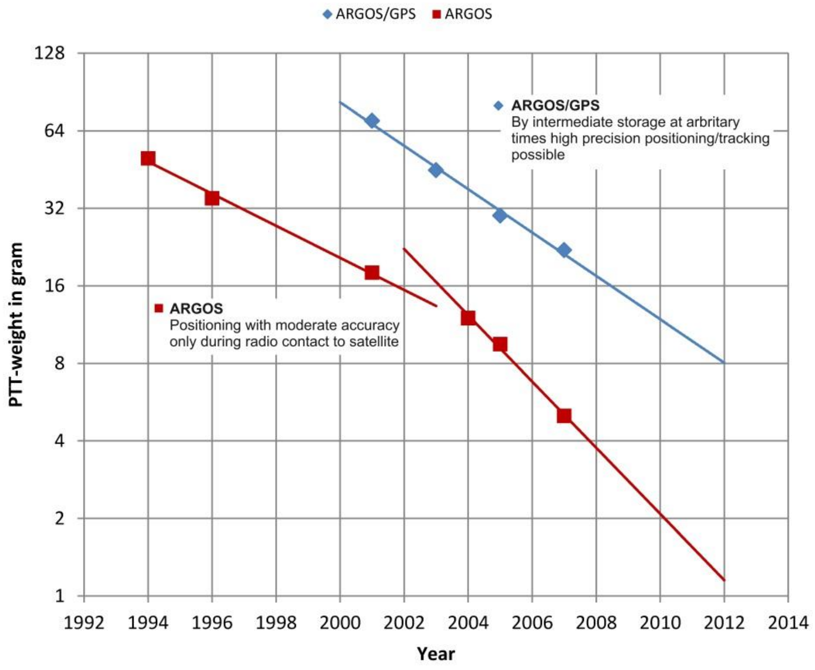


Fig.3: Weight reduction from ARGOS PTTs with solar cell over the years.

For the animal tracking only low flying satellites with orbit altitudes of 300 to 1000 km can be used, because the distances between satellite and transmitter need to be small. Those satellites have high relative speeds to the animals, but at the same time short contact times with their respective sources.

The Doppler frequency displacement changes continuously during a fly-over. This has negative and positive effects.

On the one hand it is difficult to filter the individual signal of a specific animal and on the other hand the Doppler frequency (red or blue in fig. 2) can also be used for determining a position. This system is used for the ARGOS-Doppler location process. During a given fly-over, 3 to 5 Doppler shifts - caused by radiated signals of the satellite - are measured along the s-shaped Doppler curve on the weather satellite.

Because frequency and orbit of the satellite are known, the position of the animal can be determined within one to a few hundred meters. In practice, however, position errors of 10 to 100 km happen often.

Developments in weight reduction of ARGOS-PTTs

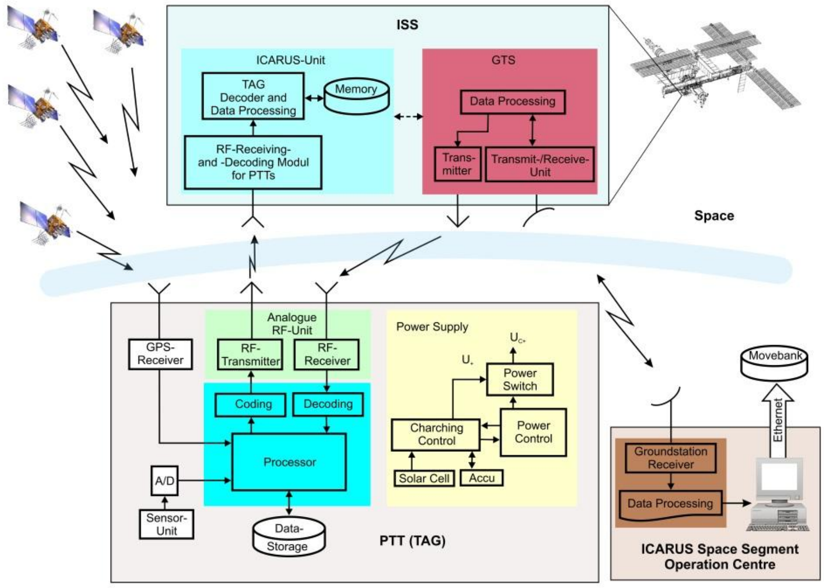
The first “small PTTs” weighted several kilogram. Today the ARGOS transmitters are suitable for smallish animals and weigh a minimum of 5 grams (fig. 3, red line). Birds weighing at least 200 g can be equipped with this. From about 10000 bird species 1500 can be monitored. In the year 2004 a great advance in the development was made in terms of weight reduction. Through using a large-area solar cell the battery size was reduced. From then on the development followed Moore's Law. However, you can see that the extrapolation at the end of the marked trend line is too optimistic. There was no weight reduction after the 5 gram version. Also the small transmitters still deliver untrusted Doppler location data, which need to undergo complex control processes.

If you equip the transmitters with GPS receivers, the location accuracy can be increased but so will the weight. ARGOS-GPS transmitters weigh around 22 gram at present, which means they are only usable for about 500 bird species (fig .3 blue line).

ICARUS – Animal tracking with the help of the International Space station ISS

The operative tracking system ARGOS demonstrates the principle how one can observe animal movement via a satellite network worldwide. New possibilities for extreme miniaturization and system development open up step by step, aided by the steady progress in the sector of mobile communication.

a



a

Most of the animal species are so small that in terms of mass reduction and data rate we have to gain one to two orders of magnitude to be able to monitor them globally. Broad systematic approaches as well as a flexibly compiled experimental program, which the ICARUS project represents, are called for. Its draft (fig. 4) provides the International Space Station ISS as the basis of experiments, which is used in order to develop optimal tracking procedure in relation to energy consumption and reliability. In addition, tracking data collected by ICARUS are being transferred via Ethernet to data banks like for example “Movebank” (fig. 1, www.movebank.org) and are made available to research groups all over the world.

Other special features of ICARUS on the ISS are that aerospace equipment can operate under laboratory conditions, i.e., as far as possible special tests for radiation, vaccum and temperature are not needed. During periodical supply flights new equipment can be transported.

The ISS enables a wide experimental and operational field which is interesting for scientists in the area of biosphere observation as well as engineering. It is for this reason that ICARUS is kindly sponsored by DLR and ESA and supported by international organizations like FAO and UNEP/CMS (United Nations Environment Programme - Convention on migratory species).

Early findings of ICARUS

Initial demonstration set ups for conceptual studies were conducted by the German "Steinbeis-Transfer-Center for space flight" and at the University Stuttgart on behalf of the Max Planck Institute for Ornithology and financed through the innovation fund of the Max Plank Society. First transmitters with commercial components emerged. Their balance in terms of weight and power consumption are promising:
Through a higher degree of integration, for example by ASIC (application-specific integrated circuit), GPS transmitters are getting lighter.