Biomimetic studies for future space missions

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Motivation and current activities

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Motivation: Constraints of space missions

Space missions have to cope with harsh conditions and uncertainty imposed by space environment. In addition, strict financial but even more technological demands have to be met and hence new approaches of system design are required. Key issues to be met include:

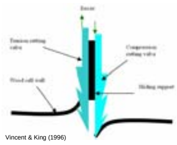
Robustness: tolerance to mechanical disturbances such as vibrations during launch and re-entering orbit

Autonomy: situation self-awareness, decision taking, reconfiguration, repair

Lightweight and **compactness**: stringent constraints on mass and volume

Adaptability: both structural and behavioural

→ **Biological systems could inspire space technology concepts**



Vincent & King (1996)

Manning (2005)

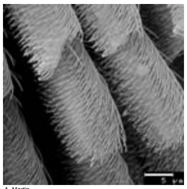
Probing the sub-surface ground with insect-inspired drills

Conventional drilling systems require heavy machinery, external force application, and immense power supply.

Biological drilling systems such as the ovipositors of wood wasps (*Sirex noctilio*) use a technically different drilling principle: The drill consists of two interlocked pieces moving along each other. Drilling is characterised by subsequent substrate compression and downward movement of the drill (see figure).

As a consequence, these drills do not need to be made of a though material and the driller needs not to apply high force as the drill 'pulls' itself into the substrate.

(Study completed with D'Appolonia and the Universities of Bath and Surrey)



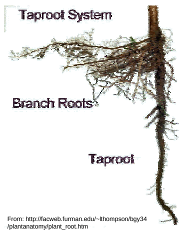
A. Martin

Attachment inspired by spider's legs

Aside from Velcro, there is a need for a space compatible reusable attachment system. As sticky fluids will evaporate in space vacuum ("outgassing"), standard adhesive systems do not qualify.

The 'dry' adhesive system of, e.g., freely hunting spiders rely on van der Waals forces and hence qualify for use in space environment. As a consequence we aim at technologically mimicking the spider's dry attachment system for use in space systems.

(Study in progress with University of Udine)



From: http://facweb.furman.edu/~lthompson/bgy34/plantanatomy/plant_root.htm

Plant roots as a model for soil penetration

The reduced gravity on small celestial bodies (e.g. moons, asteroids, comets) requires tight anchoring of landing modules. Conventional anchoring devices are tough and heavy structures that have to be pushed into the ground similarly to drills.

Plant roots actively penetrate the ground without application of high external forces, anchoring reliably in soils of various types. Mimicking the ground penetrating mechanisms of plant roots will enable an autonomous and reliable fixation of descending modules on e.g. the Martian surface.

In addition this concept allows for subsequent scalability and in a further step extraction of, e.g., minerals and water from the celestial body for either analysis or use within the space module (for in situ resource utilisation).

(Study in progress with Scuola Superiore S'Anna and University of Florence)

The ACT Approach

The Advanced Concepts Team (ACT) is a **think-tank** located within the European Space Agency (ESA).

The ACT **identifies research areas** that appear to be promising for application in future space missions and **develops research projects**.

These projects are made public in **calls** promoted on our website and in the **Ariadna Newsletters**. Research groups from universities of all ESA member states are invited to tender by submitting **research proposals**.

Proposals are then evaluated by the ACT and one proposal will be chosen for a study lasting two to six months.

Studies are **conducted jointly** by the university research team and the responsible contract officer of the ACT (e.g. Biomimetics: Tobias Seidl).

Each study is financially supported by the **Ariadna** scheme with a lump sum that will be paid upon completion of the contract.

The ACT explicitly encourages non-space-related research groups to join in!

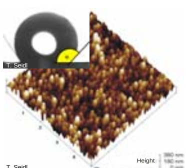
Take a flyer or ask Tobias Seidl for details!

Possible future directions

R. Wehner

Autonomous navigation of robotic exploratory vehicles

Successful navigation in an unknown environment requires the ability to employ different navigational strategies (egocentric and exocentric) and decide for the currently most reliable one. Among others, the desert ant *Cataglyphis fortis* qualifies as a model for autonomous navigation and the search for minimal algorithms.



T. Seidl

Antifouling and self-cleaning by particle repellent surfaces

Space missions with human personnel face humidity-induced fouling, especially in electrical installations and life support systems. Missions to planetary surfaces suffer from clogging of sensors and actuators by fine dust particles. In both cases, surfaces with reduced adhesive properties could aide towards more reliable designs.

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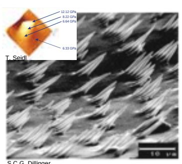
Vibration tolerant lightweight design

Biological systems, as well as most technical systems, have to avoid possibly fatal vibrations, especially those in the resonance domain. In consequence, vibration damping is an integrated part of biological constructions such as grass stems, bones or mussel shells.



T. Seidl

S.C.G. Dillinger

Multifunctional materials inspired by the arthropod cuticle

Advanced material composites combine features such as mechanical gradient behaviour, integrated sensors, and local surface properties (e.g. enhanced attachment or repellence). The arthropod cuticle is a model for advanced multifunctional composites and hence will be in the focus of biomimetic research on future space missions.

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