

Colonies of ANTS supporting the advanced habitation and development of space MC34-55

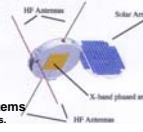
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An introduction to ANTS

ANTS is a system architecture based on three key principles.

1. Multi-level autonomy
2. Specialization & division of labor
3. Coordinated behavior

The architecture is an analog of social insect colonies. Individual elements are highly autonomous, highly capable, but highly dependent on each other to meet system goals.



Evolution towards ANTS-based systems

ANTS draws on established technological trends.

1. **Advanced computing & communications**
 - High performance computing
 - Reliable & autonomous systems
 - Reconfigurable systems
2. **Agent-based systems**
3. **Distributed Systems**
 - Multi-agent systems
 - Distributed in space and size (chips to constellations)



Development approach

Ongoing research is centered at NASA Goddard SFC.

1. **Architecture development**
 - ANTS & Distributed Space Systems
2. **Mission/System conceptualization**
 - Prospecting Asteroid Mission (RASC)
 - Advanced Solar Imaging Radio Array (proposed)
 - Saturn Autonomous Ring Array (RASC proposal)
3. **Autonomy & Agent Technology Development**
 - Spectral Analysis Agent (w. UMBC & WPI)
 - Space Technology 8 - Radio Astronomical Imaging (w. JPL)
4. **Software modeling & simulation**
 - ANTS-Sim (multi-agent / multi-spacecraft)
5. **Engineering models**
 - Addressable Reconfigurable Technology (proposed)

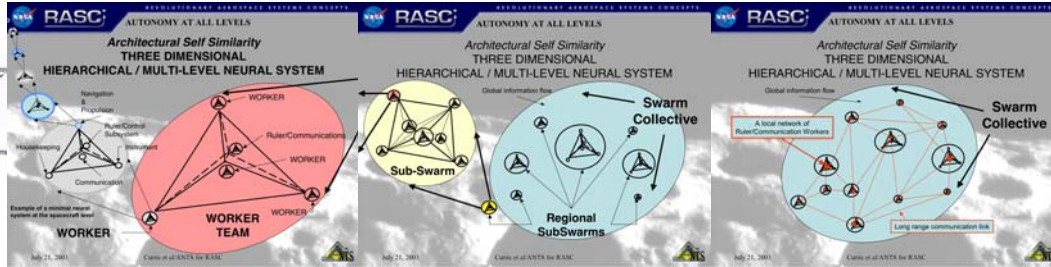


Summary Results

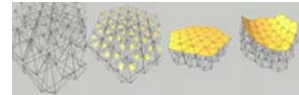
1. ANTS architecture for DSS study & design
 - Rethinking the role of the spacecraft bus
 - From mission focus to infrastructure
2. ANTS architecture has been applied to the problem of exploring the Main Belt Asteroids.
 - Mission concept in place, trade studies outlined
 - Next step: simulations
3. Research into ANTS has spun off a near-term mechanical design concept for an adaptive structure (ART).
 - Next step: engineering models & simulation
4. Initial concept for Saturn Ring exploration developed
5. ANTS-Sim models & simulation still in development
6. Onboard Radio Astronomical Imaging in study for STS
 - Advanced onboard computing plays a key role

Web site: <http://ants.gsfc.nasa.gov/>
 ANTS has been supported by GSFC Internal Research & Development and NASA's Revolutionary Aerospace Systems Concepts program. NASA/HRCCP supported work on onboard Radio Astronomical Imaging.

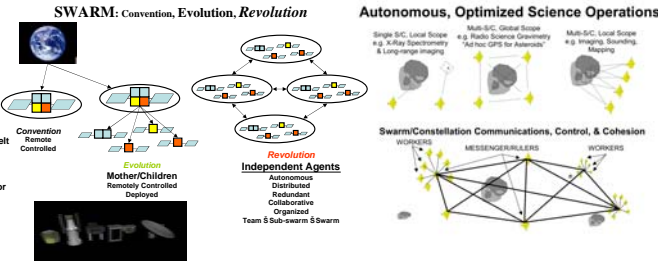
End-to-End Architecture



NANO-TECHNOLOGY ← **SWARM** → DISTRIBUTED SPACE SYSTEM
Division of Labor



SPECIALIZATION & TEAMWORK



Near-term Application

Addressable Reconfigurable Technology (ART) for Large Space Structures

Products

- Reconfigurable ART structural mesh
- ART Truss Architecture
- Mission Engineering Model
- Transition Plan for ART implementation

Objectives

- Scalable reconfigurable ART structural mesh
- Mass and volume efficiency
- <math>< 1 \text{ kg/m}^2</math> area with a pathway to $\text{g/m}^2</math>$
- Packing factors that scale with fabrication tech
- Macro 10x - Micro 10³x Nano 10³x
- -1E: Design of Micro-scale ART Nodes
- -2E: Macro models of multi-Node ART structure

Participants

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Steven A. Curtis	Brugh & Brugh
Cynthia Y. Cheung	NASA/GSFC
Neil Gopalakrishnan	NASA/GSFC
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Schedule and Funding

Milestone	Year 1	Year 2	Year 3
Milestone 1	Brugh & Brugh		
Milestone 2		ART Truss Architecture	
Milestone 3			ART Truss Implementation

Advanced Application

Autonomous Nano-Technology Swarm

Prospecting Asteroids Mission

ANTS/PAM Mission Concept 2020

1. Assembly & release
2. Self propelled transit
3. Long-Range Operations
4. Swarm (Fly by) Operations
5. Repeat steps 3 and 4.
6. A messenger carries findings to Earth when needed.

Key locations: Asteroid belt, Asteroid(s), Lagrange Point Habitat, Earth.

SCALABLE SELF-RECONFIGURATION

ANTS: Evolution of Near-Earth Space
"It's a small solar system after all."

- 1930s Balloons
- 1950s LEO
- 1970s GEO
- 2010s Mars
- 2030s Asteroids

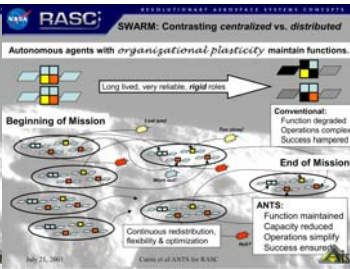
GOES
M. David 1977

Mars 2001

Asteroids 2002

Travis I 1960

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The Robert C. Byrd Green Bank Telescope, 100 meter diameter, with an Active Surface of 2300 actuators for high frequency radio astronomy. Improvements will include heliostatic focusing and laser ranging for improved surface figure. Detail shows truss work behind the reflecting surface (BRAGMATONS). Addressable Reconfigurable Technology (ART) will enable launch packaging and in-space deployment of such structures.

GSPC Laboratory For Extraterrestrial Physics, Planetary Magnetospheres Branch
NASA **Autonomous Nano Technology Swarm**
 GSPC *The Final Unexplored Frontier: The Asteroid Belt*
 IR&D

- Survey 1000 asteroids a year.
- Mission functions distributed across a thousand specialized spacecraft.
- Present nano-spacecraft extended into pico-spacecraft regime (~ 1 kg).
- On-board computation, artificial intelligence, heuristic systems.
- Emergent behavior at single, group, and swarm system levels.
- Solar sail propulsion. 0.8 AU/YR.
- Long & Short range communication.

About ten spacecraft subtypes based on science sensors, in two general classes.

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