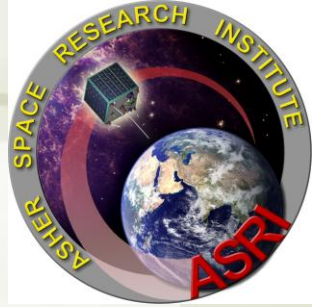


The Helen and Norman

ASHER SPACE RESEARCH INSTITUTE

Ehud Behar, Director

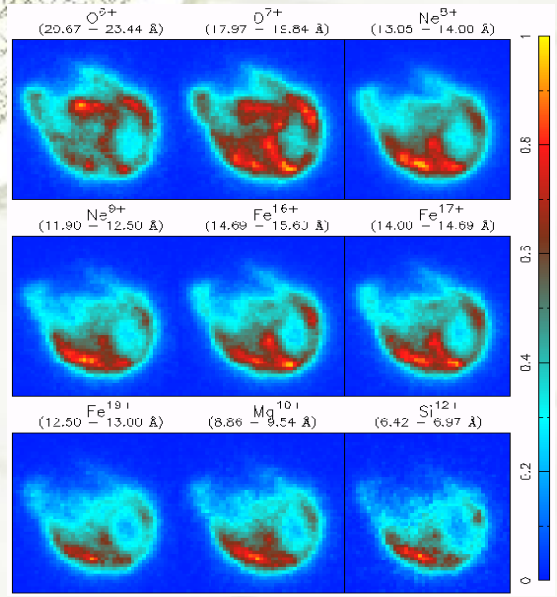
Dahlia Greidinger Agri Sensing, February 2011

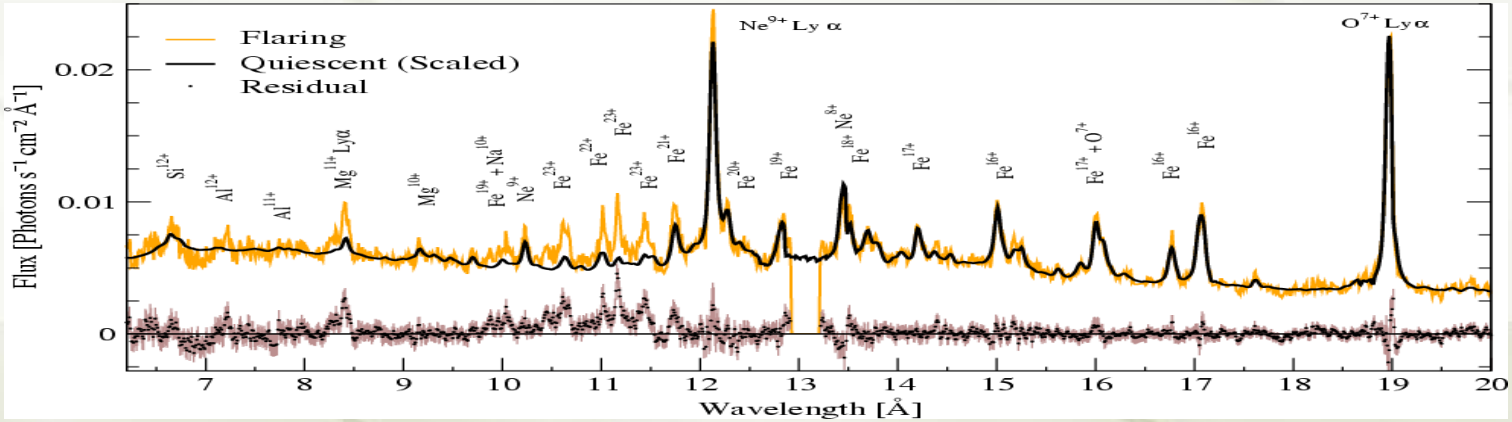
Israel's Vision of Satellite Remote Sensing Systems

ASRI Mission

- Expand the frontiers of space research
- Combine innovations in science and technology
- Investigate the Universe and Earth from space
- Develop new technologies for space vehicles and space communications
- Promote scientific and technological education
- Foster collaboration with industry and academia worldwide

Astronomically-Remote Sensing (hyper-spectral)





Space Remote Sensing Agri-Sensing 2011

- Total of 13 papers

- MODIS - III
- Landsat - II
- Venμs - II
- Hyperion, MERIS, ERS-2, RADARSAT-2, Sentinel-2 - I
- Farmsat - I

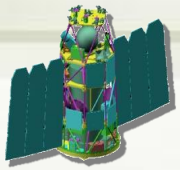
Out of ~ 100 papers

Talk Outline

- Israel in Space
- Space Science Missions
- Remote Sensing from Space
  - Venμs
  - Shalom
- Prospects
  - Policy
  - Space Research
- Concluding Remarks

Israel's 20+ years in Space

OFEQ 9 2010



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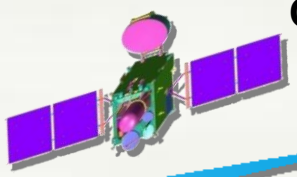
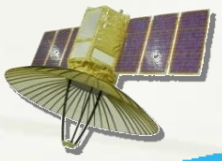


TechSAR 2008



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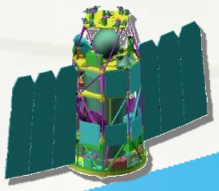
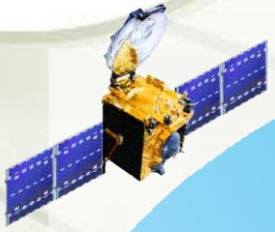


EROS B 2006

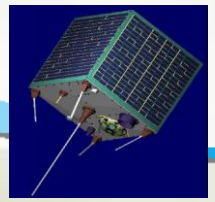
Amos 2 2003



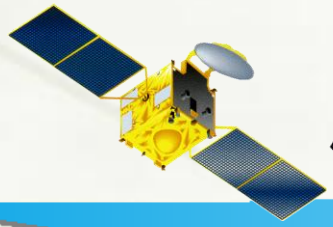
OFEQ 5 2002

EROS A 2000

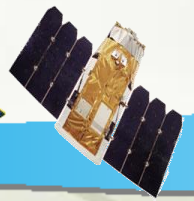
TechSat 2 1998



Amos 1 1996



OFEQ 3 1995

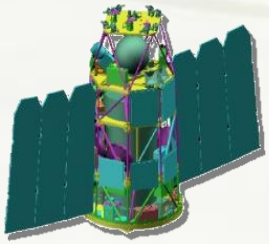


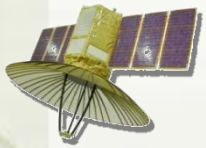
OFEQ 2 1990

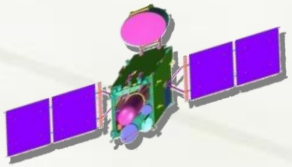
OFEQ 1 1988

Admirable Capabilities

- Launching (*Shavit*)
- Imaging (*Ofeq*)
- Communications (*Amos*)
- Radar (*SAR*)



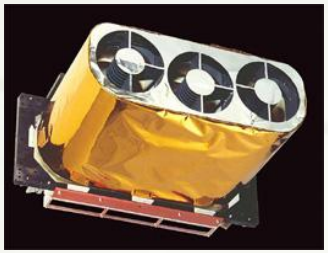


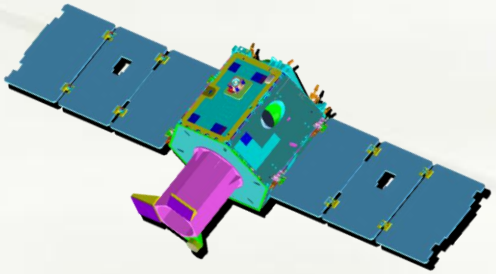


- Small-but-Smart Satellites

Transition from Military to Civil

- Commercial: Amos, EROS
- Scientific
  - TechSat - Student Project
  - TAUVEX - UV telescope for astronomy
  - Venμs - Earth Observations
  - "Shalom" Earth Observations
    - with hyper-spectral camera
  - MuSAR with NASA to Venus



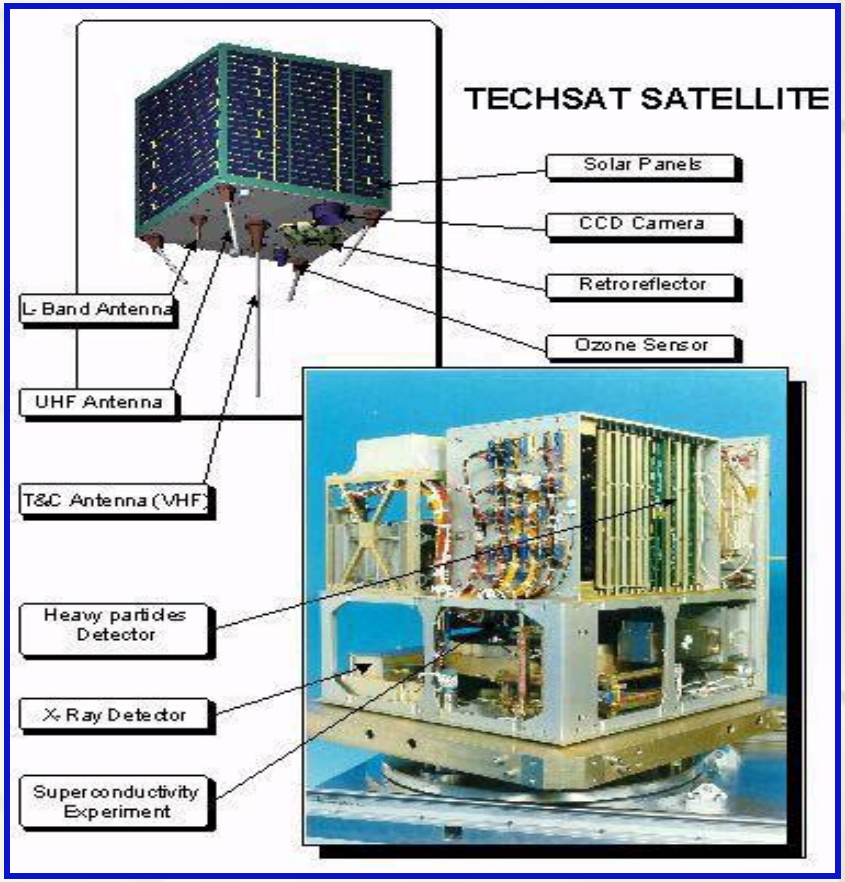


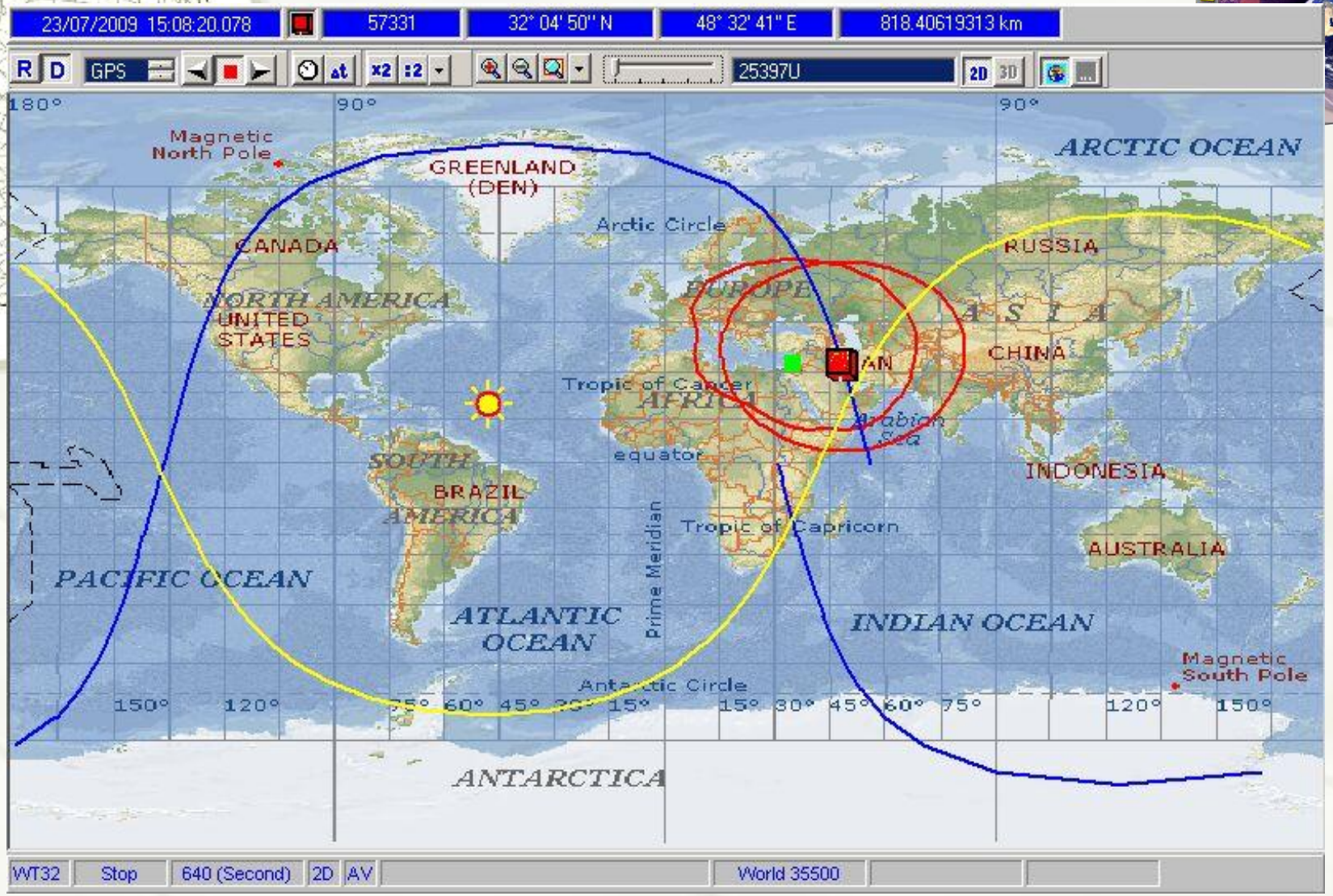
Gurwin-Techsat II MicroSatellite

Technion student project

Launched 1998 operational 12 years

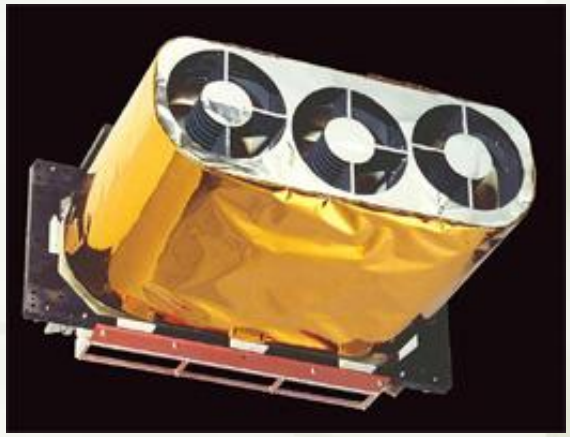
World Record for Longest Living University Satellite

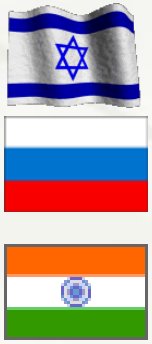


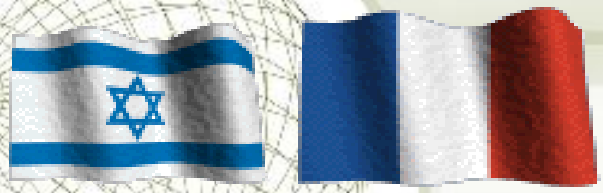

23/07/2009 15:08:20.078
57331
32° 04' 50" N
48° 32' 41" E
818.40619313 km
R D
GPS
x2 :2
25397U
2D 3D
180°
90°
90°
Magnetic North Pole
GREENLAND (DEN)
ARCTIC OCEAN
Arctic Circle
CANADA
RUSSIA
NORTH AMERICA
UNITED STATES
EUROPE
A S I A
CHINA
Tropic of Cancer
AFRICA
Arabian Sea
equator
SOUTH AMERICA
BRAZIL
INDONESIA
Prime Meridian
Tropic of Capricorn
AUSTRALIA
PACIFIC OCEAN
ATLANTIC OCEAN
INDIAN OCEAN
Magnetic South Pole
Antarctic Circle
150° 120° 75° 60° 45° 30° 15° 15° 30° 45° 60° 75° 120° 150°
ANTARCTICA
WT32
Stop
640 (Second)
2D
AV
World 35500

TAUVEX

- **T**el **A**viv University **UV** **Ex**plorer
- Three 20 cm UV telescopes built by ELOP
- On shelf for ~ 20 yrs
- Launch slated for
  - originally Shavit
  - 1991 SRG
  - 2004 GSAT-4
    - 2010 Dumped
    - April 2010 GSAT-4 crashes
  - ???

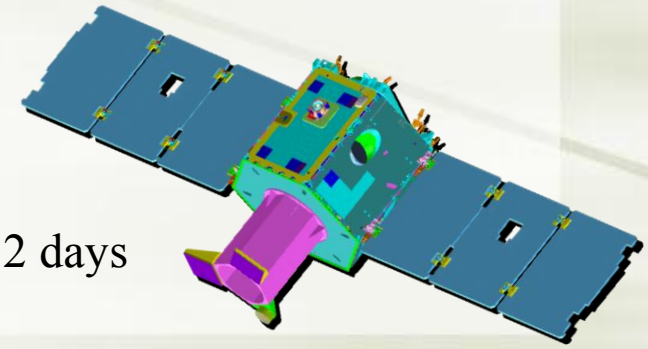


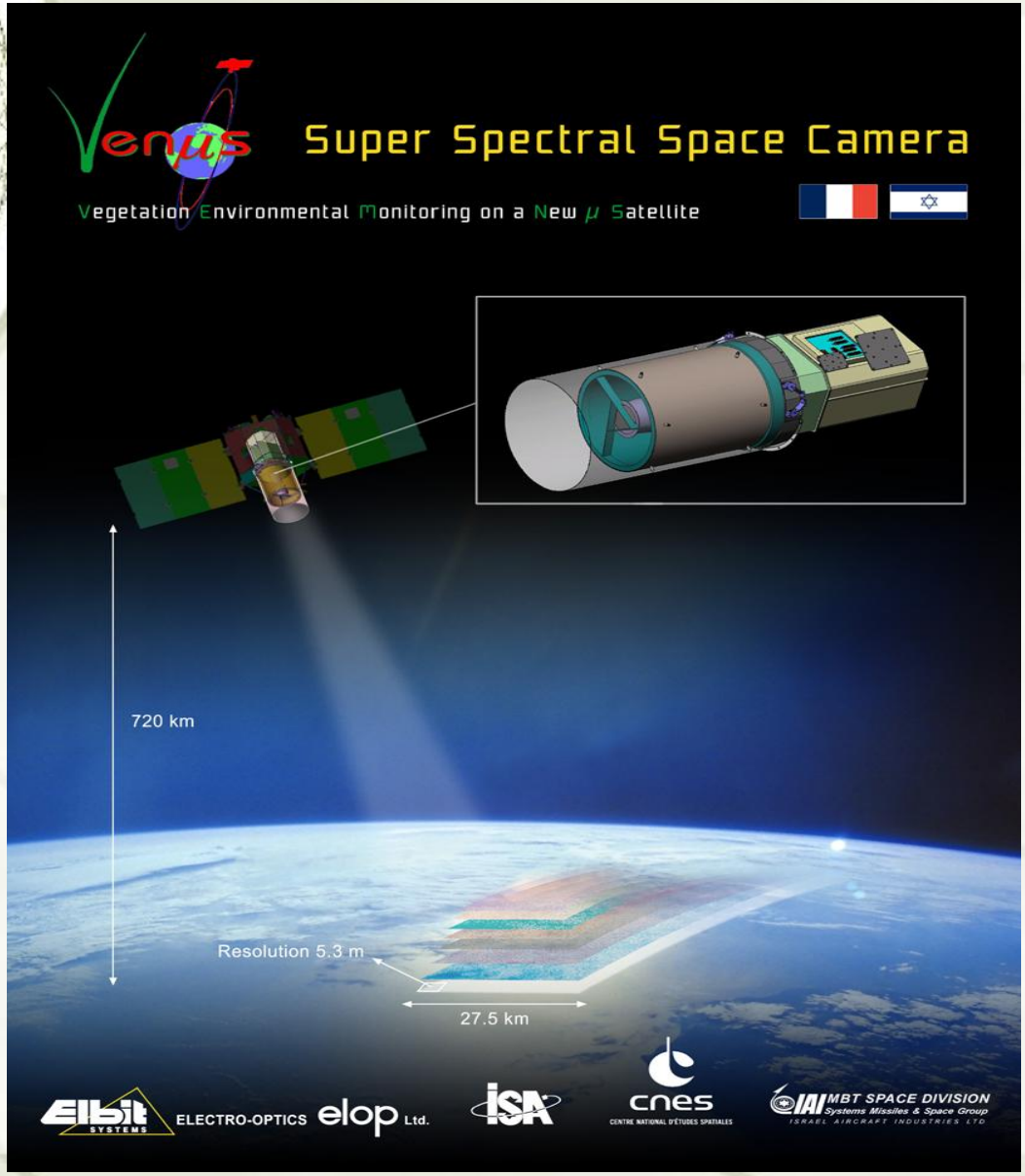




Vegetation and Environmental monitoring on a New μicro Satellite

- Partners:
  - ISA – Israel Space Agency
  - CNES - Centre National d'Etudes Spatiales
- **Scientific Mission and Image Ground Segment (CNES):**
  - Mission scientists : Gérard Dedieu & Arnon Karnieli
  - Multi-spectral camera (12 bands, resolution 5-20 m)
  - Monitor land, vegetation, water quality, …
- **Technological Mission and Center (ISA):**
  - Test first Israeli electric ion-thrusters
  - Station keeping - Precise orbit repeat every 2 days
  - Change orbit from 720 km to 410 km





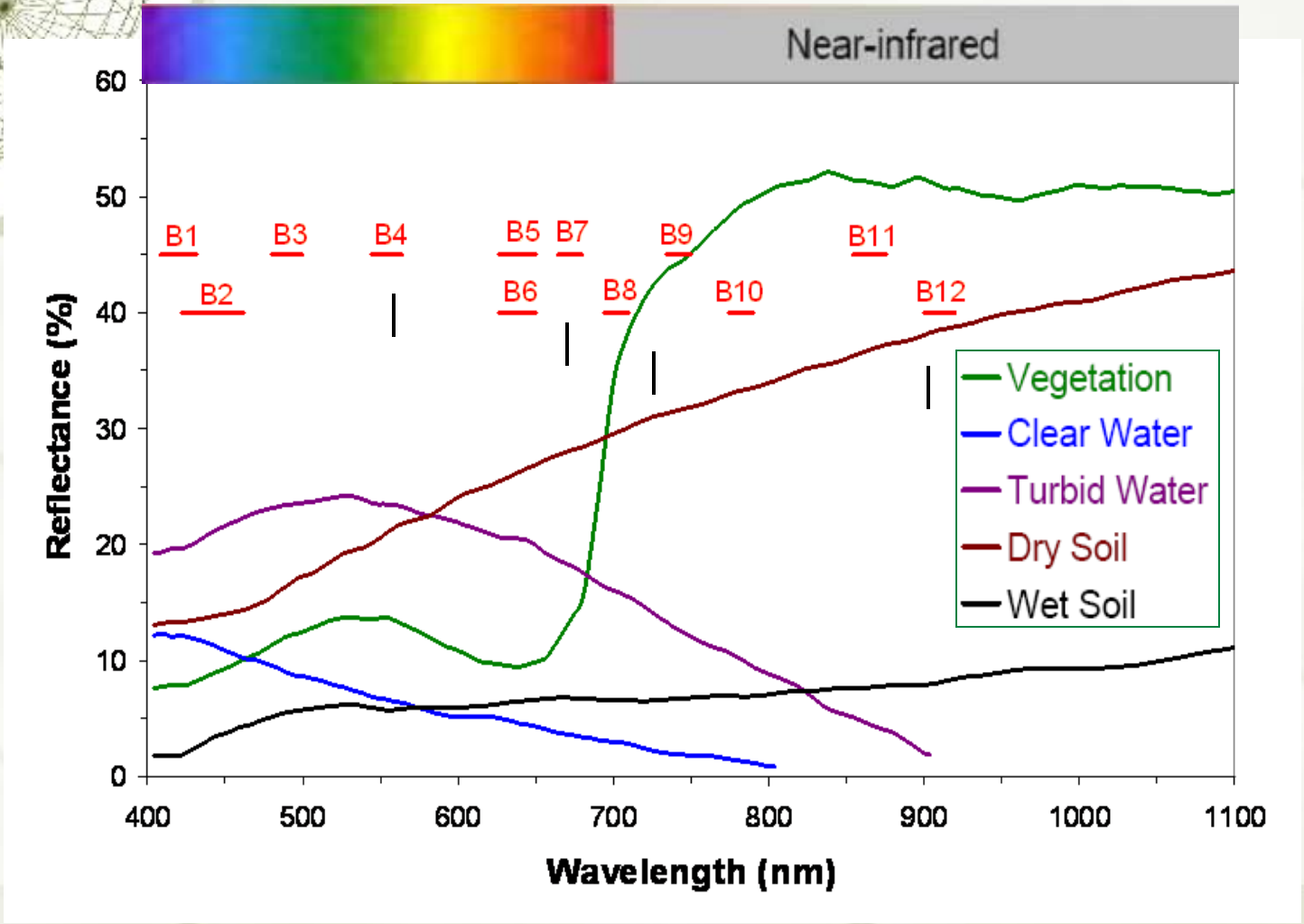
ASHER SPACE RESEARCH INSTITUTE
ASRI

Elbit Systems
Electro-optics - Elop

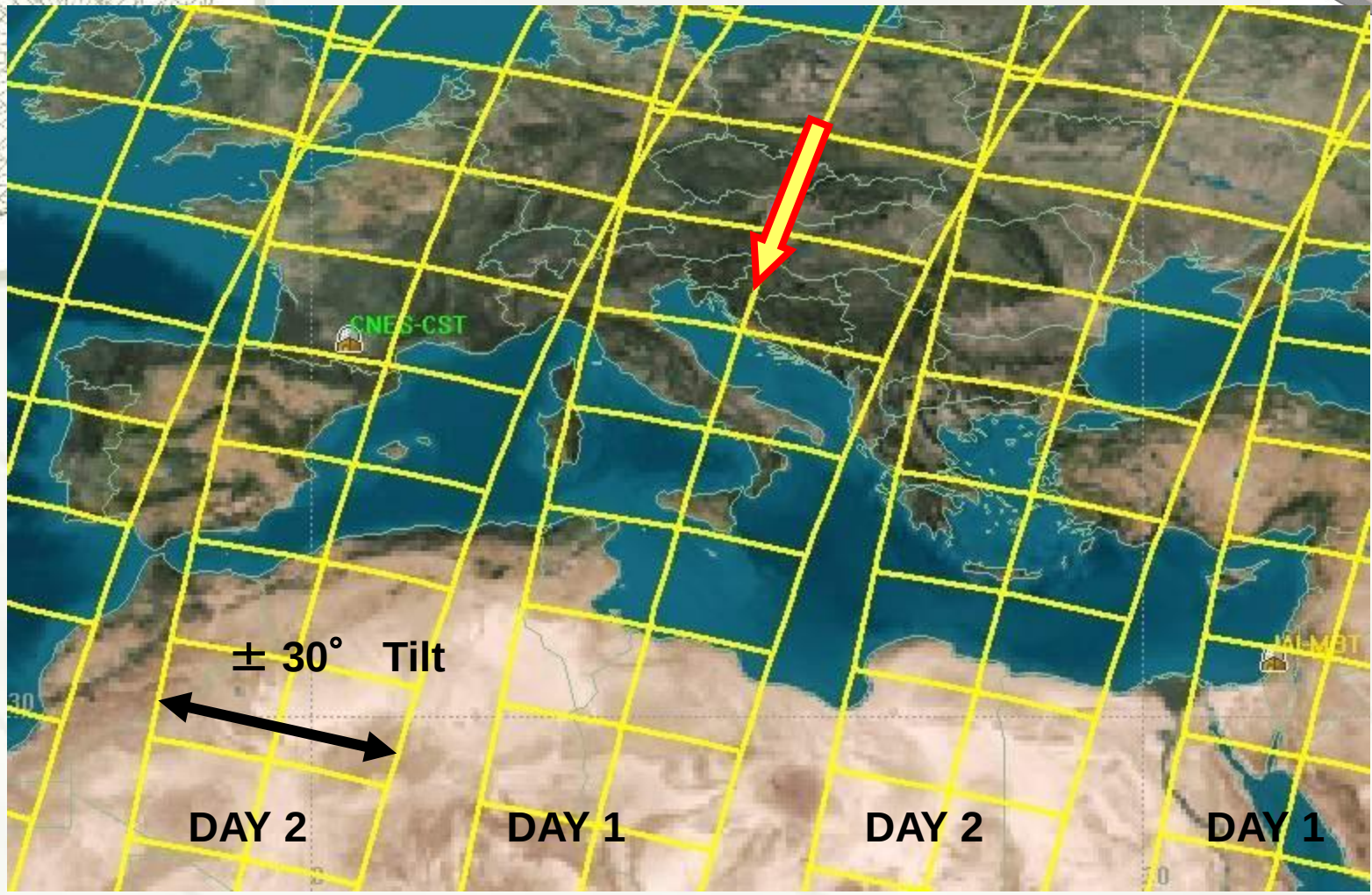
High Resolution Spatial Spectral and Temporal RS

- **Orbit**: Sun Synchronous circular orbit at **720** km, **~98°** inclination
  - **Precise 2-day revisit time** (± 5 min over mission) for minimum directional reflectance effects
  - (absolute) geometric pointing within ~1.5 m (3 m over time)
- **Performance overview**:
  - Spectral Imaging over waveband **400 - 920 nm**
  - FOV (cross-scan x scan): @ 720 km 2.2° x 1.5° (**27.56 km x 18.8 km**)
  - Angular resolution: < 0.5'' Ground Sample Distance (GSD) @ 720 km: **5.3m**
  - Radiometric calibration to < 5%
  - 30° tilt along and across track
  - On-ground binning (no on-chip binning) for higher S/N
  - Power: **<90W** (Imaging operation), **<14W** (Standby)
  - Telescope System Mass: 35 kg
- **Open data policy** (1 - 3 months)

Venμs 12 Wavebands

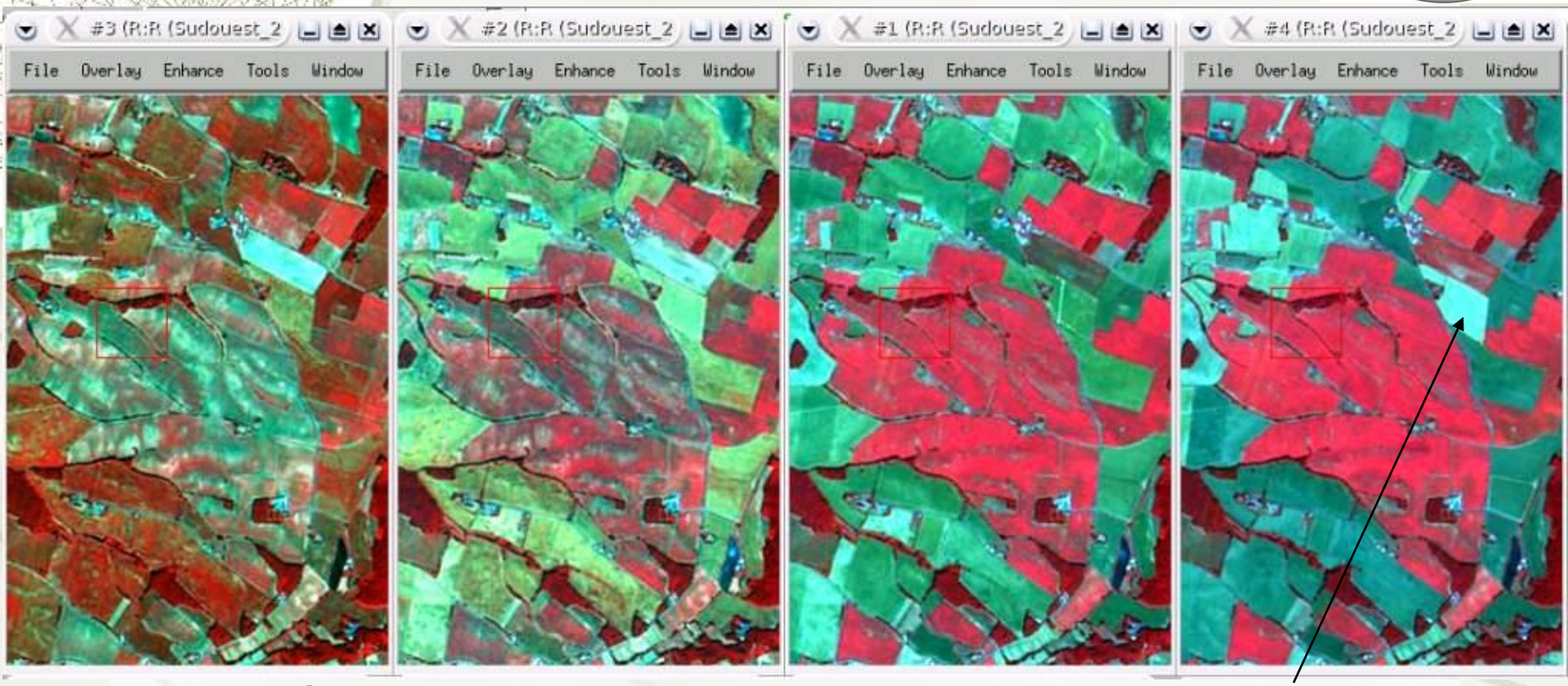


Venμs Coverage



Temporal Diagnostics

June 5th 2006 | June 14th 2006 | June 23th 2006 | June 29th 2006

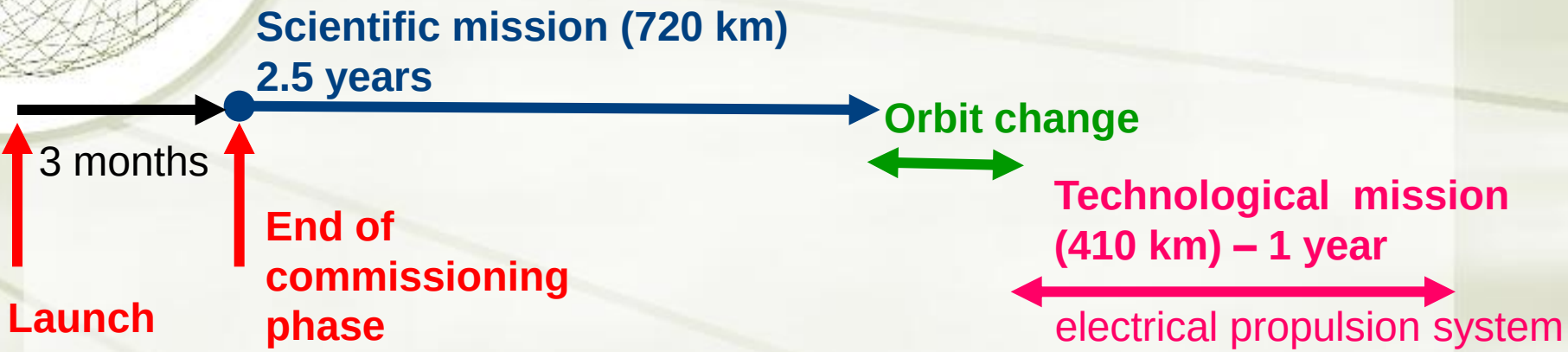


Formosat-2 images
courtesy of G. Dedieu / CESBIO

Conspicuous increase in reflectance due to wheat harvest

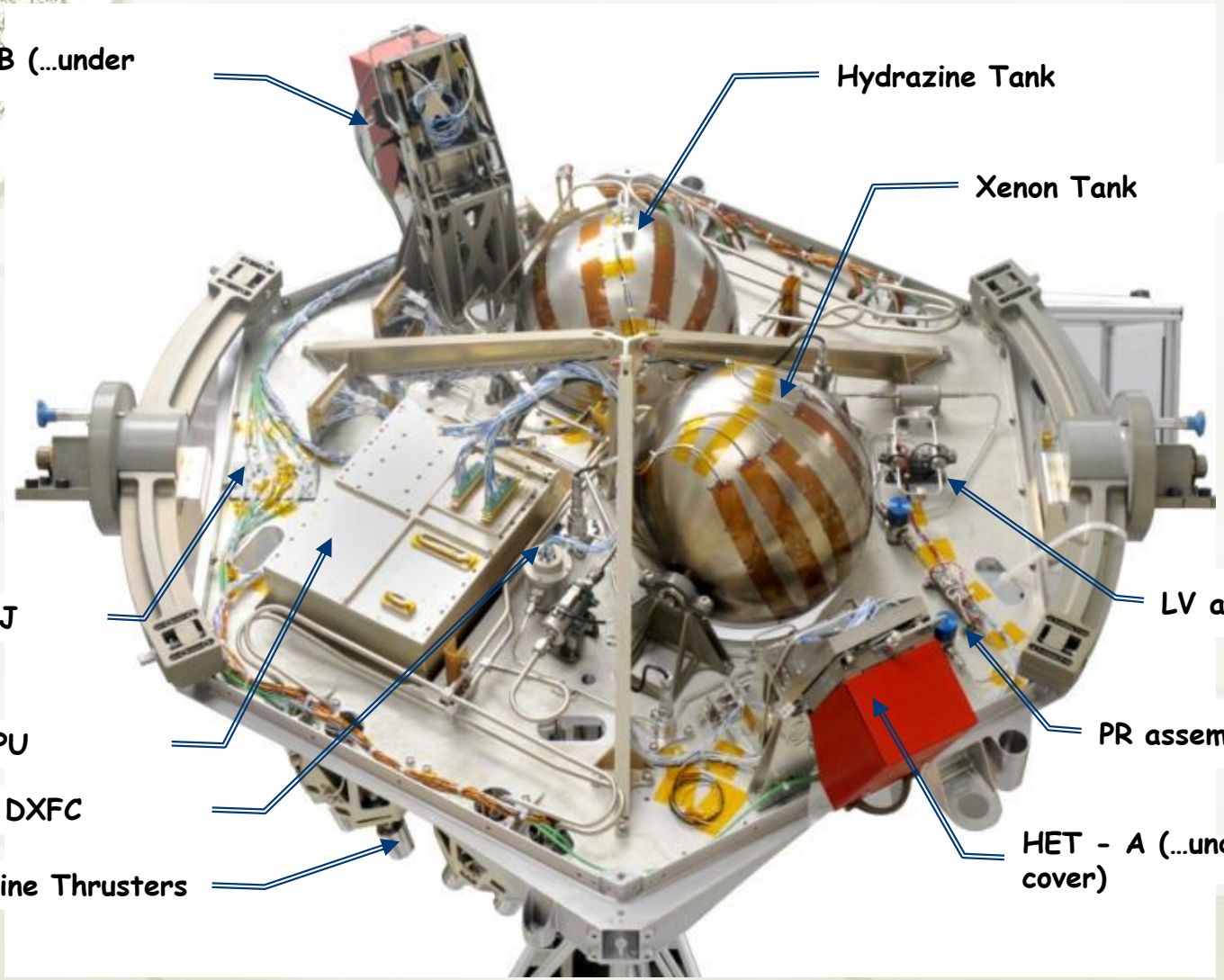
green to red (summer crops) - sunflower
red to green (winter crops) - wheat and colza

Venμs's Technological Mission



- Launch: Ariane, ISRO, SPACEX ?
- Israel's first ever electric (Hall effect) thrusters in space
- Change orbit and maintain low orbit
- Better GSD, smaller FOV, Science?

Venμs
Propulsion Base Assembly



Venμs Propulsion Specifications

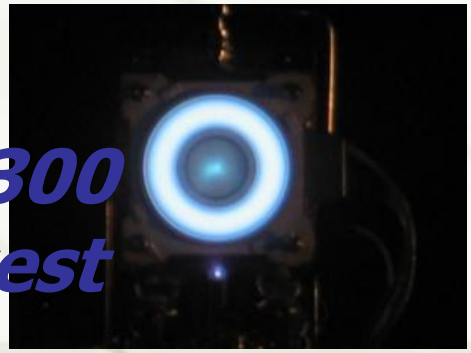
- Electrical Propulsion System (EPS):
  - 2 x Hall Effect Thrusters
  - 16 kg Xenon tank
  - Power Processing Unit, variable anode power up to 600W, digitally controlled
  - Fully redundant design
- Chemical Propulsion System (CPS)
  - 8 x Thrusters, 1N
  - 7 kg Hydrazine tank
  - 2 redundant branches
- Total mass (including base plate structure) < 50 kg

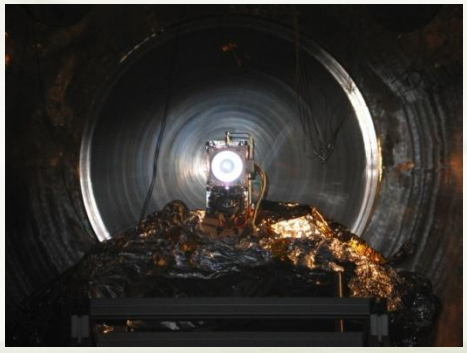
HET-300

Isp @ 300W : >1300s
Thrust @ 300W: ≥15mN
Total Impulse: >90 KNs
Operating Power: 250W ÷ 600W

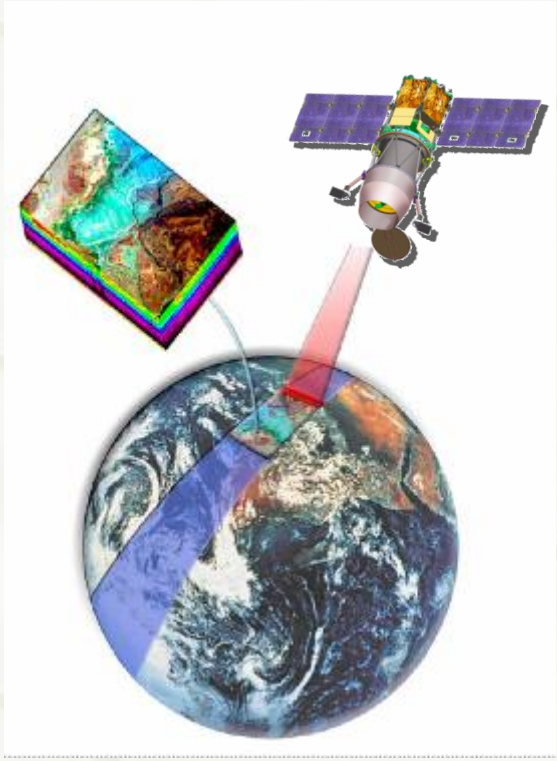
1N Thruster

HET-300 Fire test



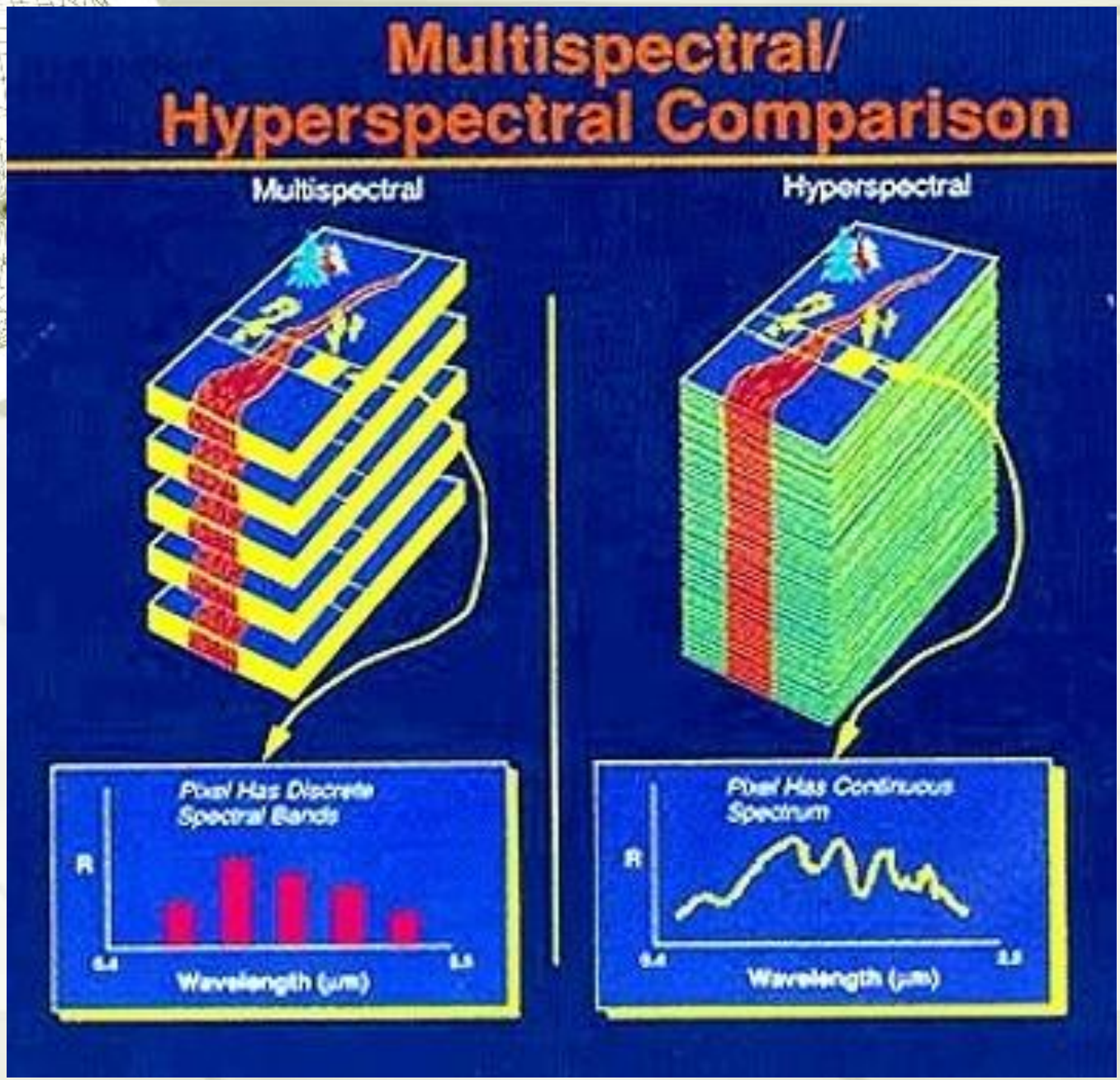


Scientific and Commercial HyperSpectral Satellite System



Spaceborne Hyperspectral Applicative Land and Ocean Mission

"SHALOM" Program


Multispectral/
Hyperspectral Comparison
Multispectral
Hyperspectral
Pixel Has Discrete
Spectral Bands
R
Wavelength (μm)
Pixel Has Continuous
Spectrum
R
Wavelength (μm)

SHALOM Orbit (*Preliminary Design Goals*)

- LEO Sun-Synchronous
- Altitude: 500…900 km
- Along track image size: 200km
- Area coverage per day: 200,000 km^2
- Pointing accuracy: 0.3 km
- Target location known to better than 0.2 km without GCP
- Revisit: <4 days
- Maximum angle off of nadir: $\pm 30^0$

Hyperspectral Instrument (Preliminary Design Goals)

- Swath: 10km, GSD: 10m
- Spectral range: 400 nm – 2500 nm
- Spectral resolution: 10nm
- S/N of 100 (2000 nm) - 600 (650 nm)
- Absolute radiometric accuracy: 4%
- Spatial registration between VNIR - SWIR: 0.2 GSD
- Panchormatic channel co-aligned with hyperspectral channels
  - GSD of 5 m (goal 2.5m)
  - spectral range: 400 nm - 700 nm

Elbit Systems
Electro-optics - Elop

Talk Outline

- Israel in Space
- Space Science Missions
- Remote Sensing from Space
  - Venus
  - Shalom
- Prospects
  - **Policy**
  - Space Research
- Concluding Remarks

Space Policy in Israel

- Israel Space Agency (ISA) established 1983
  - budget is essentially null
- "Space club" countries allocate ~0.1% of their GDP for non-military space
  - for Israel that would be $200M
- On 2009 Nov. 2 President Peres (in conjunction with the prime minister) nominated an ISA committee to seek a change

Committee Report

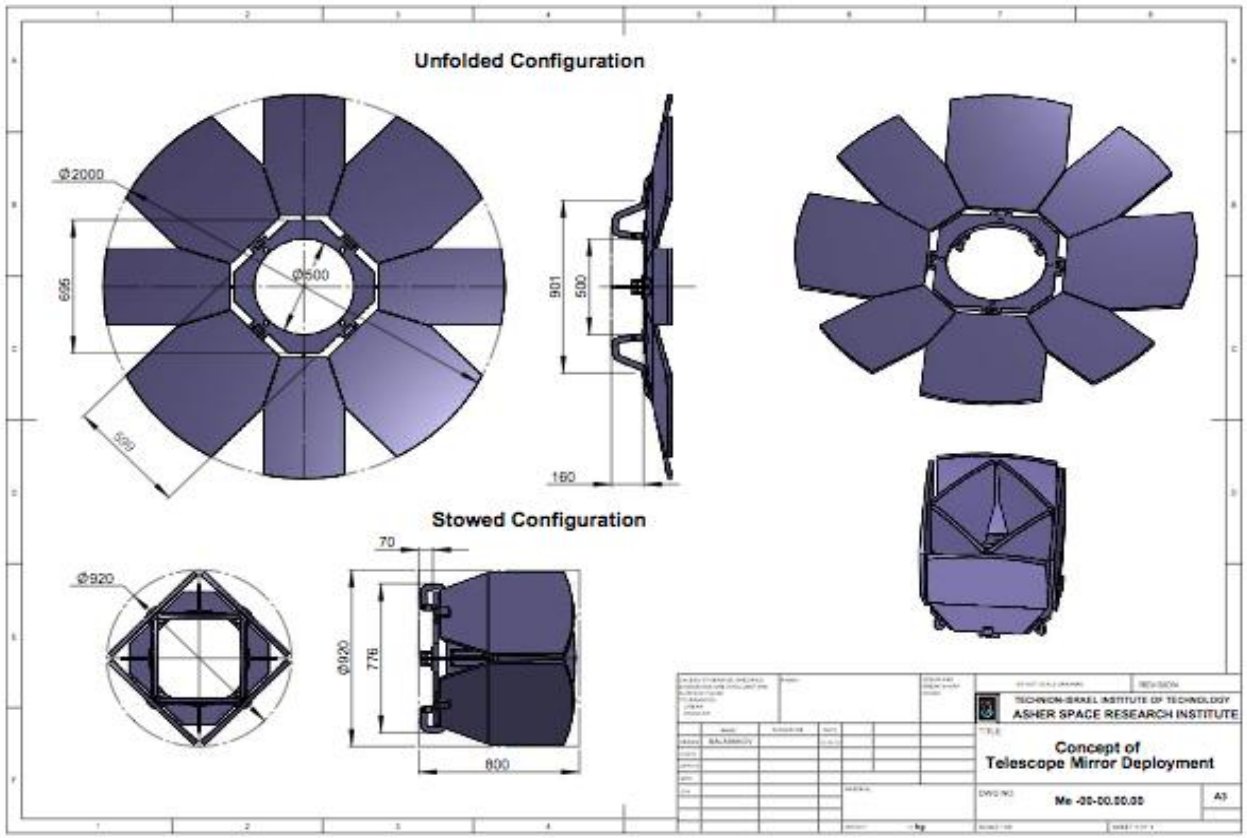
- 12 members (not a single scientist)
- Excerpts from Recommendations
  - Establish and sustain the presence of Israeli Earth and far-space observatories in space
  - Establish ISA steering committee with 3/14 scientists
  - Provide ISA with annual budget of 300 M NIS for five years
    - 70% to industry, 30% applied and basic research
  - Support space research
  - Foster international collaboration on space projects and research
- Report deliberated by government

Some Relevant Research Trends

- Advanced Optics
- Very Low Earth Orbit Design
- Electric Propulsion
- Distributed Space Systems and Formation Flying
- International Space University

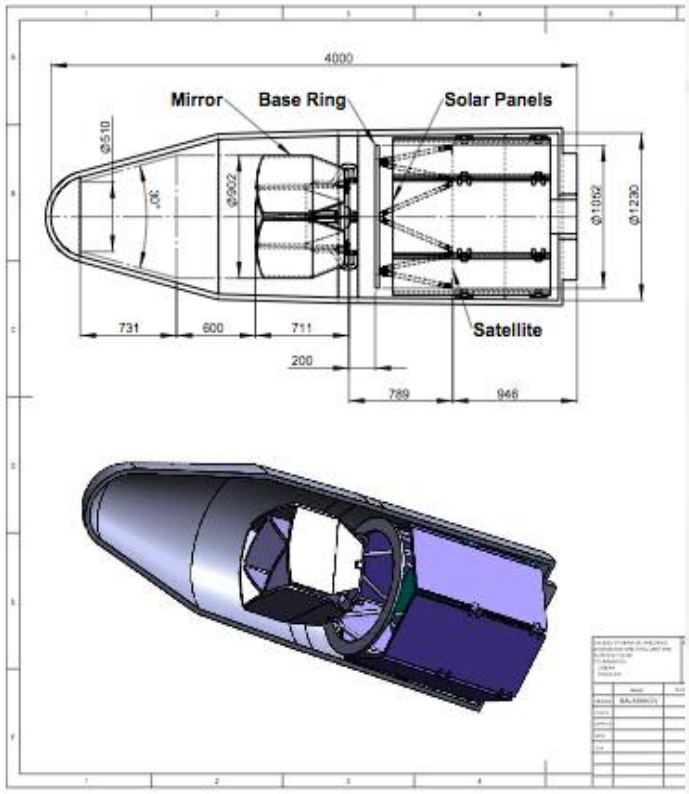
- Input from RS community is crucial

Folded Optics
When Size Does Matter



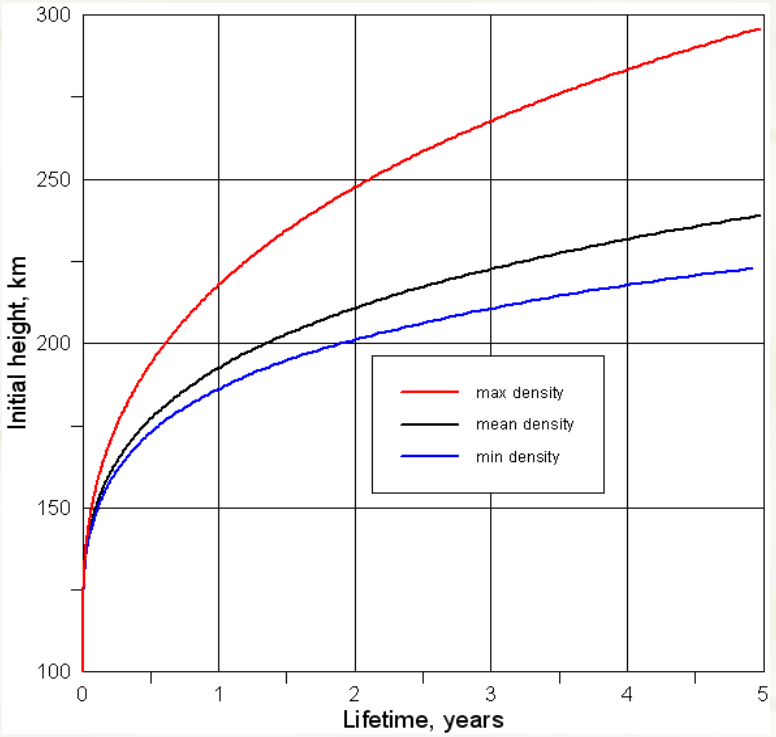
Folded Optics Challenges

- Mirror material
  - composite metals
  - thermal expansion rates
- Support and folded structure
- High precision optical alignment in space



Very Low Earth Orbits

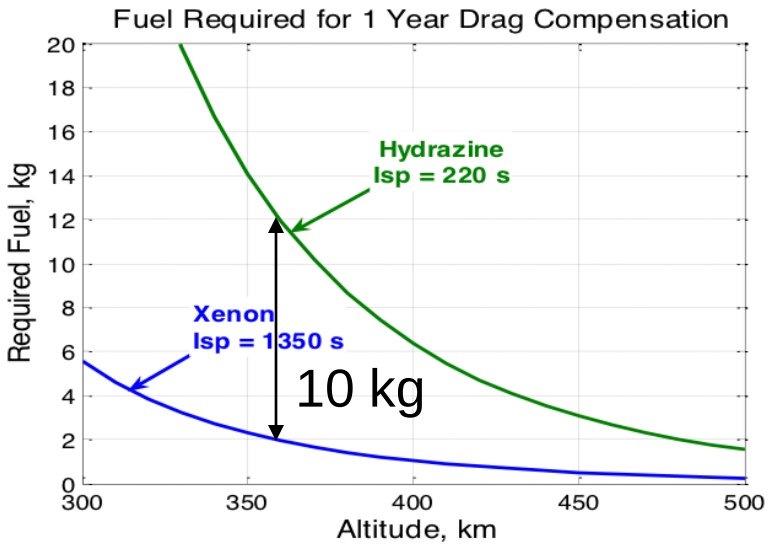
- Technion μSat program
  - Aircraft launching
  - VLEO (200 km)
  - Pros for Earth observing
    - 2x image resolution
    - 4x radio power
  - Cons
    - Requires high thrust to compensate for drag
    - 2x less FOV
    - 2x less radio visibility



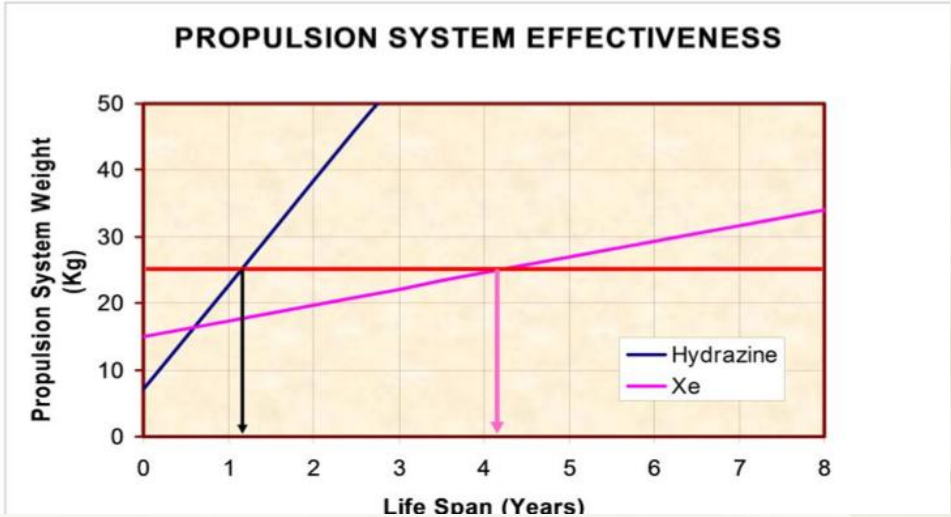
Electric Propulsion

- Ionizes and accelerates propellant (Xe)
- Uses solar energy
- Increases mission time
- Saves mission mass/money
- High specific impulse $\Delta v/g$ >1000 s
  - c.f. ~200 s for chemical thrusters
- Allows in-flight maneuvering for
  - Drag compensation
  - Orbit change / revisit rate control
  - Interplanetary flights
- Challenge: Heavier dry system

Weight Trade-Off



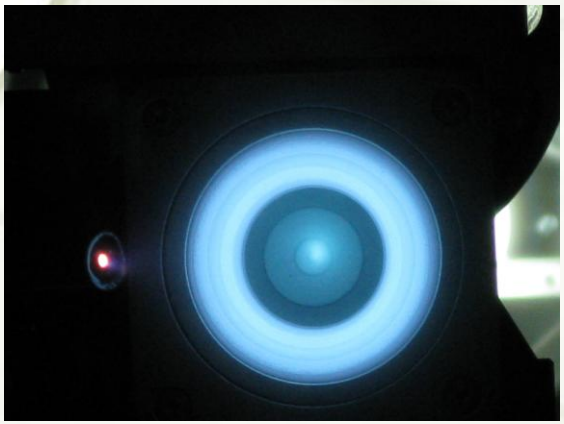
- Circular Orbit At 350 Km
- Solar Condition: Max
- Effective Cross-Section Area: 1 m^2
- Duty Ratio Of HET Thrust Applied: 0.071

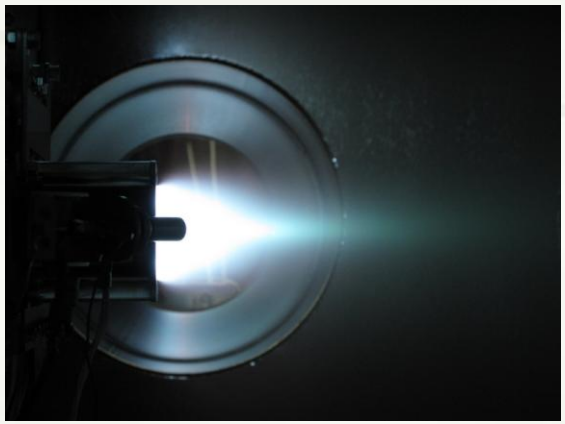


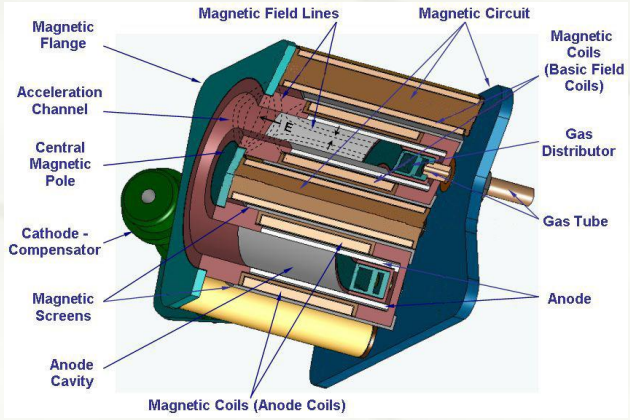
Diff. in dry systems ~ 10 kg

ASRI EP Laboratory

Head: Dr. Alex Kapulkin

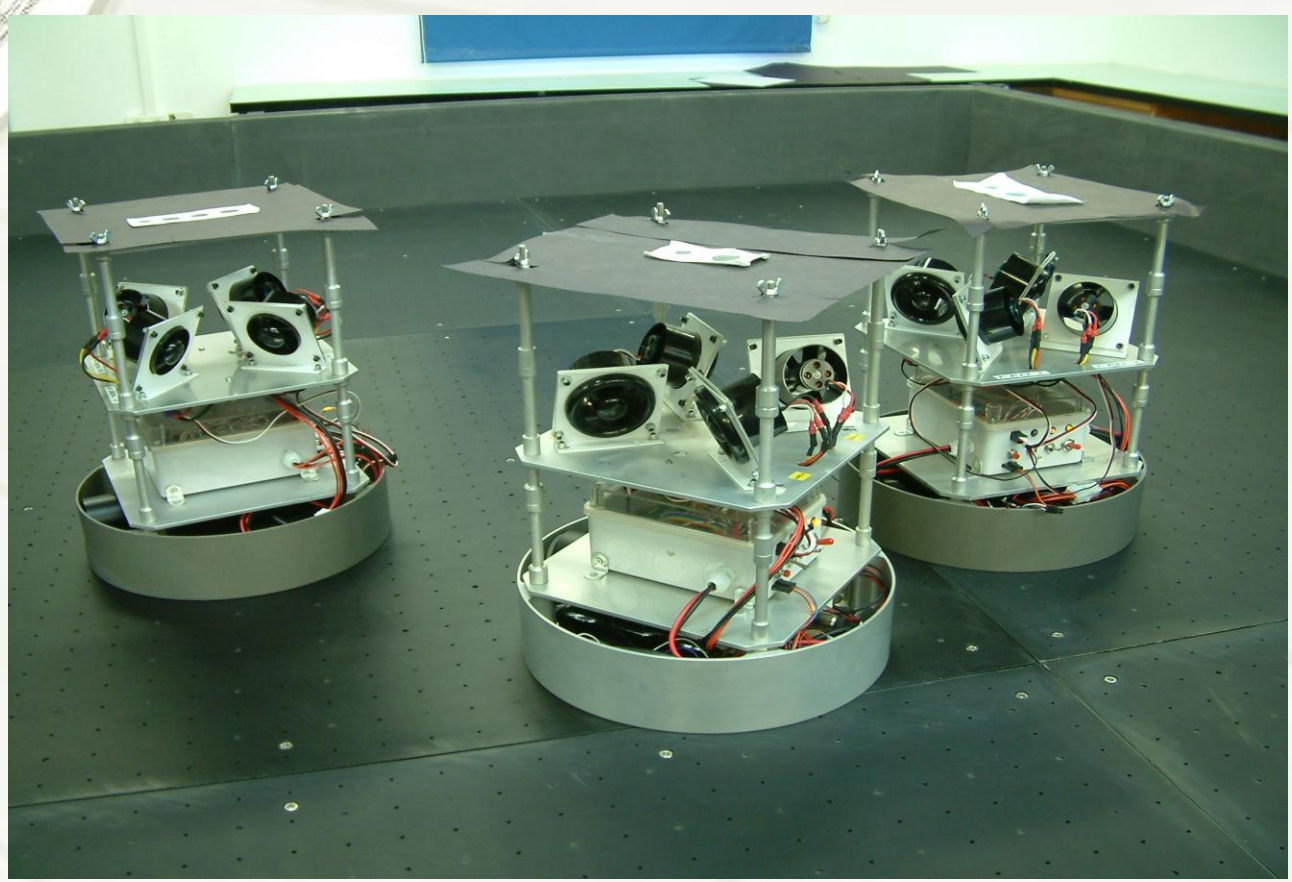






Distributed Space Systems

Head: Prof. Pini Gurfil

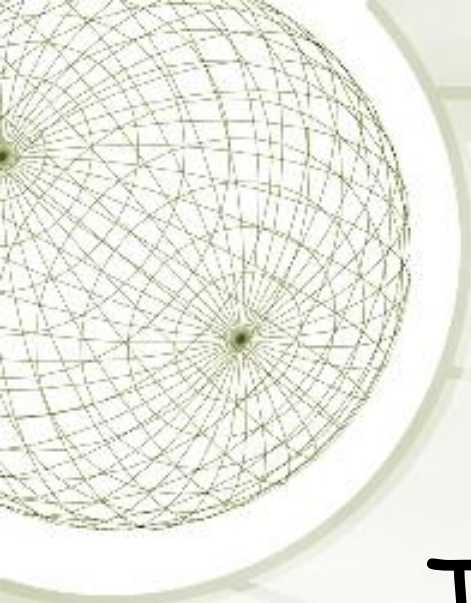


Education

- Student nano-satellite laboratory for testing new technologies
  - New ideas and collaborations welcome
- International Space University
  - Summer SSP space studies program
  - 9 week event
  - 120 students + 50 faculty
  - Technion pending proposal for 2013

Concluding Remarks

- Israel is stellar in space
- Space science has been put high on the National priority list and in particular Earth observations
- If you haven't already, this is an exciting time to start doing remote sensing from space and to make use of the growing Israeli resources
- Transition to a civil space program needs to be led by the scientific community, or at least to draw from it, please participate
- Your dialogue and collaboration with the Technion's Asher space research institute and its researchers is most welcome



Thank You Very Much

Technion/ASRI Summary

- Committed to:
  - Academic Excellence
  - Multidisciplinary Research
  - Infrastructure Laboratories
  - Ties with Industry
  - Student Projects