Putting Technology to Work in Science - How to Select Unmanned Aircraft System (UAS) for Atmospheric and Earth Surface Observations

Amit Teller, Manfred Lange, Stelios Ioannou and Christos Keleshis
Energy Environment and Water Research Center
The Cyprus Institute, Nicosia, Cyprus

The Cyprus Institute

Research Promotion Foundation

EEWRC

Acknowledgement: The APAESO project being supported by a grant of the Research Promotion Foundation Cyprus

Just before we begin...some terminology

Remotely Piloted Vehicle (RPV)

Unmanned Aerial Vehicle (UAV)

Drone

Unmanned Aerial System (UAS)

Unmanned Air Vehicle System (UAVS)

And the winner is.....(US DoD definition)

******Unmanned Aircraft System (UAS) !******

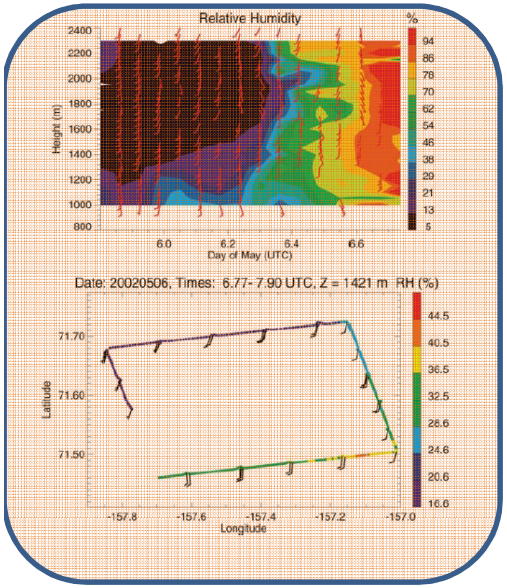
Background and Rationale

- **Geosciences research is composed of three approaches:**
  - Field observations
  - Laboratory experiments
  - Numerical modeling
- **Understanding changes in the Earth System (atmosphere, land and ocean) requires detailed observations.**

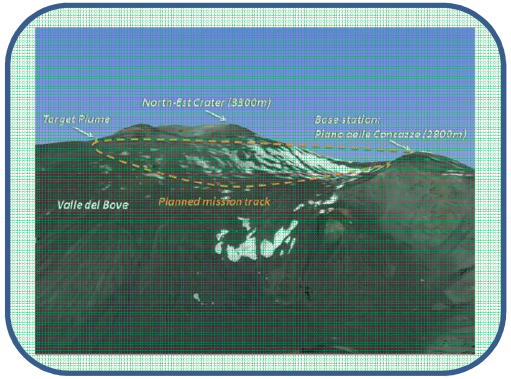
Observation method	Advantage	Disadvantage
Ground based/ in-situ	High accuracy and reliability	Low coverage in space and time
Satellite remote sensing	Global and continuous temporal coverage	Limited vertical resolution
Airborne measurements	Provide vertical resolution	Costly and constrained observing times

Autonomous Unmanned Aircraft Systems (UASs) are a promising complementary alternative

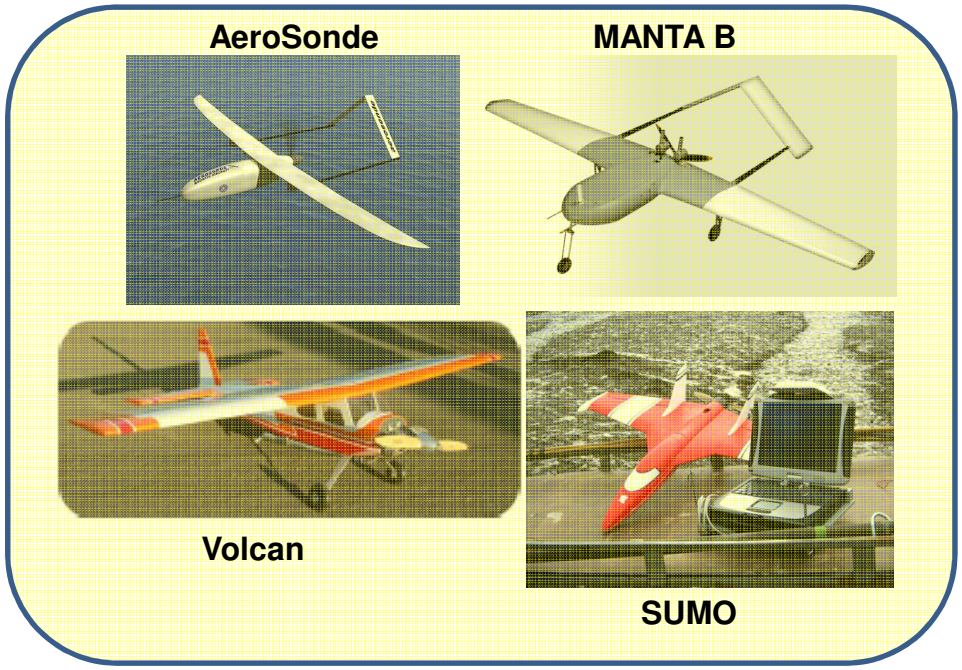
Applications of UAS in geosciences - examples

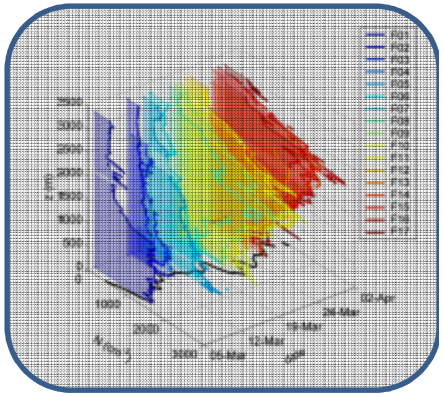


(Curry et al. 2004)

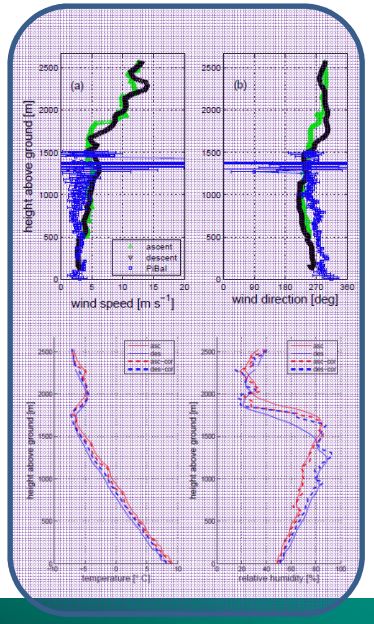


(Astuti et al. 2009)





(Corrigan et al. 2008)



(Reuder et al. 2008)

Autonomous Flying Platforms for Atmospheric and Earth Surface Observations (APAESO)

- **APAESO**
  - Limited size and weight enable a relatively large range at moderate fuel demand
  - Being operated autonomously and automatically allows systematic surveys over long distances and over relatively long times

➢ **Purpose: To carry out at high spatial resolution Atmospheric and Earth-surface observations in the Mediterranean:**

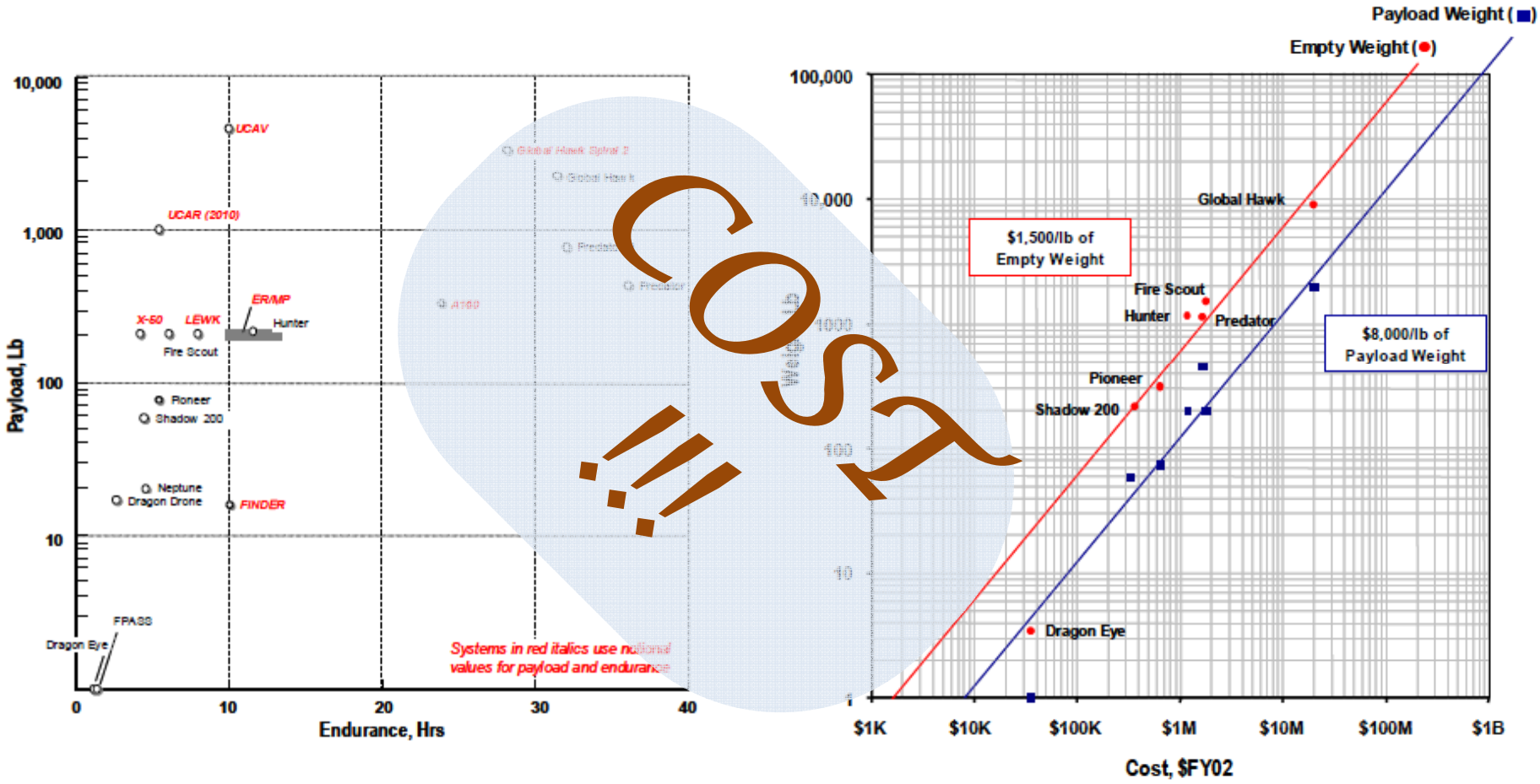
- **Physical, chemical and radiative atmospheric properties**
- **Physical, chemical and optical properties of aerosols**
- **Atmospheric dynamics**
- **Cloud physics**

- **Surface Morphology**
- **Vegetation and land use patterns**
- **Archaeological site exploration**
- **Contaminant Detection**
- **Ocean Surface Properties** *(biology, waves, currents)*

Selection considerations

- Should be commercially available because of:
  - Safety considerations
  - Easy to get flight certification.
  - Simple and fast acquisition process
- Endurance - at least 3 hours
- Radius of operation - at least 50 km
- Max. flight altitude - at least 5 km
- Payload - at least 5 kg
- Fixed wing and push propeller to avoid propeller effects
- Maximum Take Off Weight (MTOW) - 11-35 kg

The most fundamental problem…..



Preliminary selection phase

More than 1,000 platforms are currently available:

UAS that did not meet the design criteria

Model	Manufacturer	Reasons of Rejection
X1	X1	• Flight services through hiring
X2	X2	• Under development
X3	X3	• Very small payload (1.5 kg)
X4	X4	• Flight services through hiring
X5	X5	• Very small payload

Final selection phase

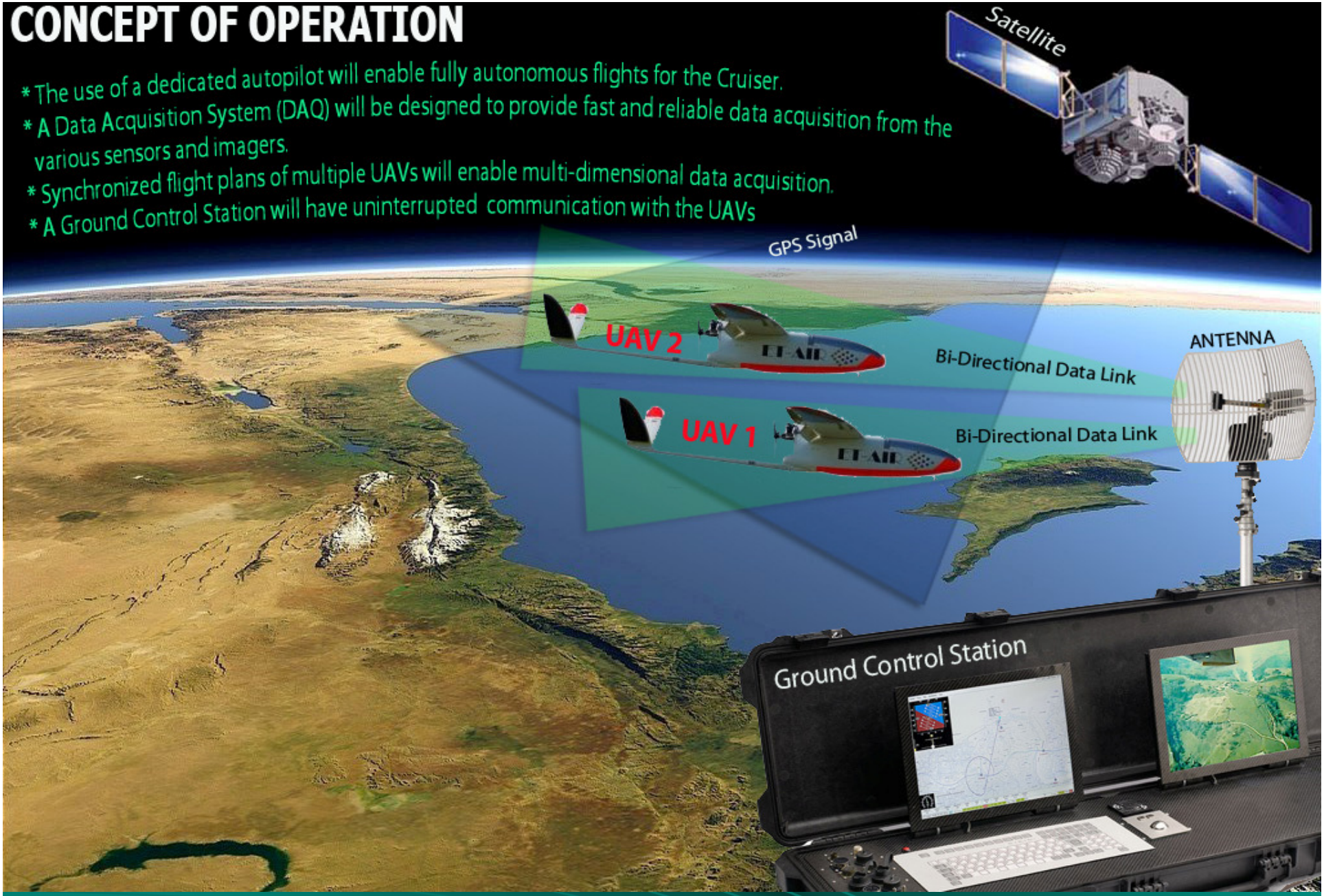




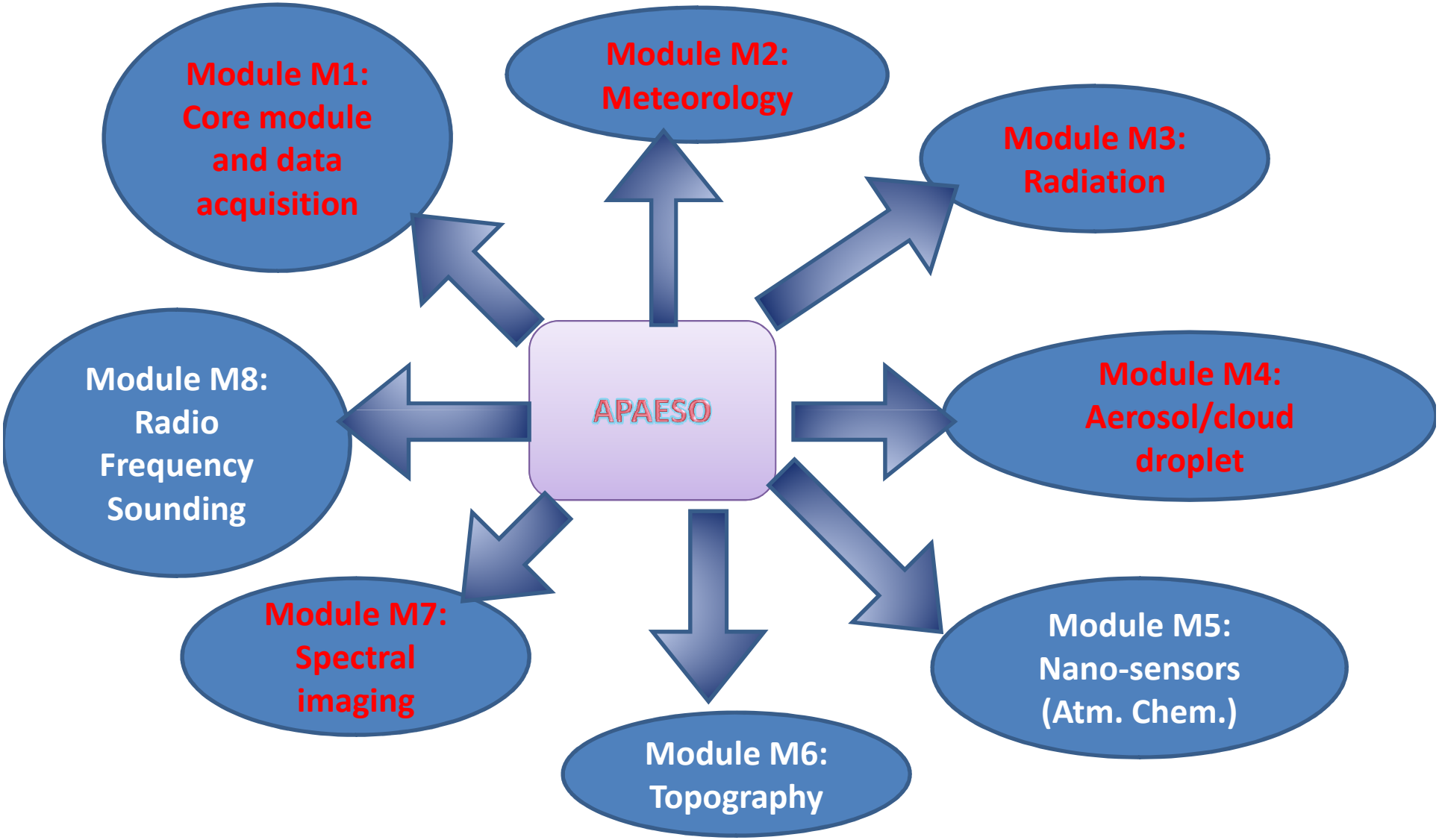
Company	Manta B	Cruiser	Fulmar	Orbiter 3	T-16
Model	ACR	ET-Air	Aerovision	Aeronautics	Arcturus
Country	USA	Norway/Slovakia	Spain	Israel	USA
Wing span (m)	2.7	3.8	3.1	2.2	3.92
Payload capacity	6.8	6	1-5	6.5	13.6
Endurance (h)	6	10	8-2	2.5 (electric)	16 (for 9kg payload)
Max. Altitude (m)	4,870	4,000	3,400	5,000	5,000
Launch Method	Wheels	Catapult	Catapult	Catapult	Catapult
Landing Method	Wheels	Belly, Wheel	Belly or Net	Parachute	Parachute

CONCEPT OF OPERATION

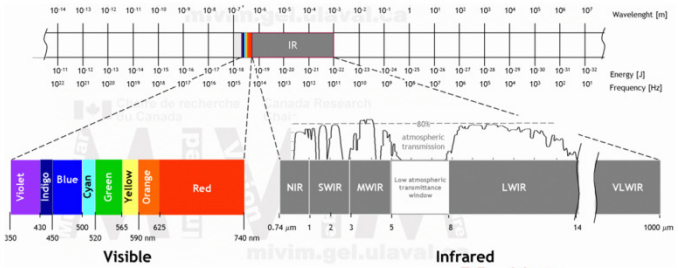
* The use of a dedicated autopilot will enable fully autonomous flights for the Cruiser.
* A Data Acquisition System (DAQ) will be designed to provide fast and reliable data acquisition from the various sensors and imagers.
* Synchronized flight plans of multiple UAVs will enable multi-dimensional data acquisition.
* A Ground Control Station will have uninterrupted communication with the UAVs



APAESO Modules



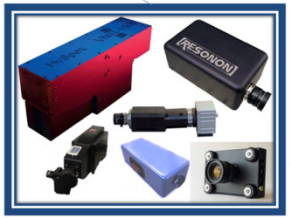
Imaging Sensors



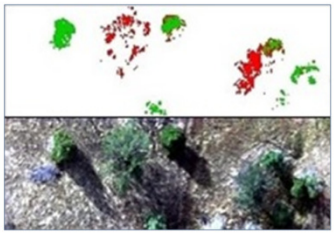
400-1000 nm Multispectral Cameras

7.5 – 14 μm Infrared Cameras

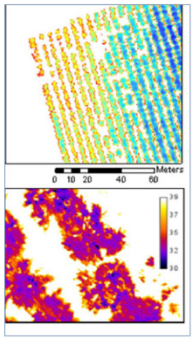
Visible Cameras



Sauran Medieval Archaeological Complex in South Kazakhstan (source: http://www.transoxiana.org/13/smagulov-sauran.php)



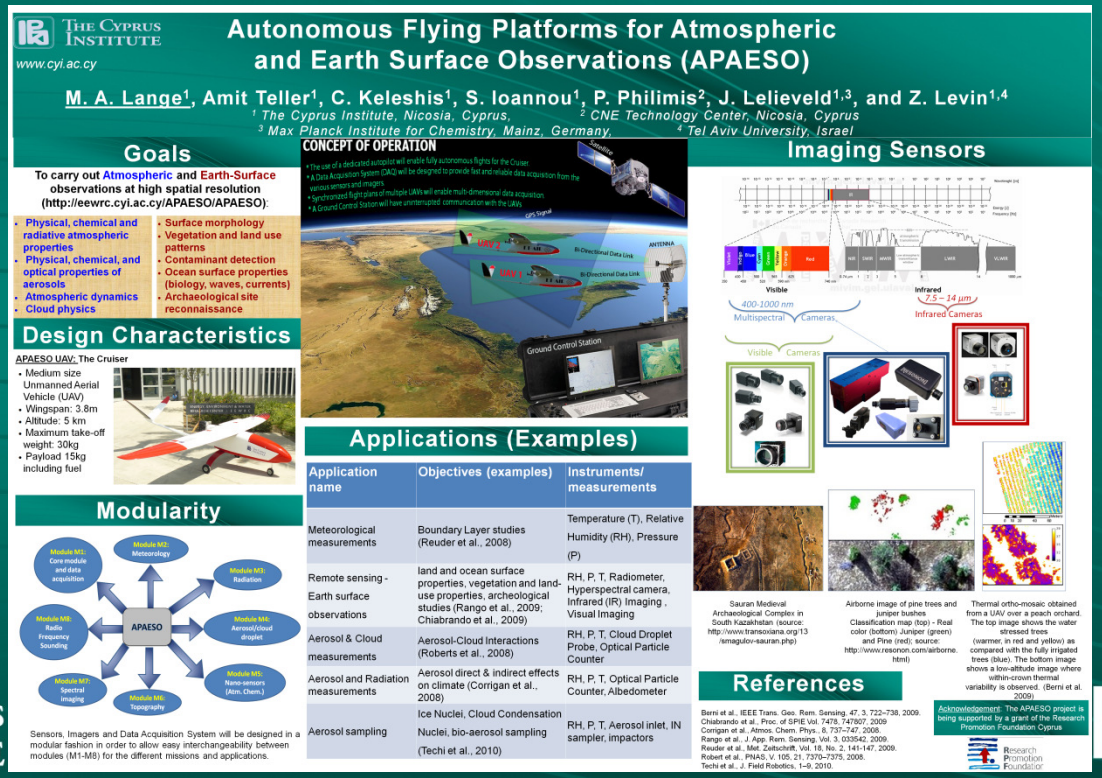
Airborne image of pine trees and juniper bushes Classification map (top) - Real color (bottom) Juniper (green) and Pine (red); source: http://www.resonon.com/airborne.html)



Thermal ortho-mosaic obtained from a UAV over a peach orchard. The top image shows the water stressed trees (warmer, in red and yellow) as compared with the fully irrigated trees (blue). The bottom image shows a low-altitude image where within-crown thermal variability is observed. (Berni et al. 2009)

Thank you !

Visit our poster



The Cyprus Institute
www.cyi.ac.cy

Autonomous Flying Platforms for Atmospheric and Earth Surface Observations (APAESO)

M. A. Lange[1], Amit Teller[1], C. Keleshis[1], S. Ioannou[1], P. Philimis[2], J. Lelieveld[1,3], and Z. Levin[1,4]
[1] The Cyprus Institute, Nicosia, Cyprus, [2] CNE Technology Center, Nicosia, Cyprus
[3] Max Planck Institute for Chemistry, Mainz, Germany, [4] Tel Aviv University, Israel

Goals

To carry out Atmospheric and Earth-Surface observations at high spatial resolution (http://eewrc.cyi.ac.cy/APAESO/APAESO):

- Physical, chemical and radiative atmospheric properties
- Physical, chemical, and optical properties of aerosols
- Atmospheric dynamics
- Cloud physics
- Surface morphology
- Vegetation and land use patterns
- Contaminant detection
- Ocean surface properties (biology, waves, currents)
- Archaeological site reconnaissance

Design Characteristics

APAESO UAV: The Cruiser

- Medium size Unmanned Aerial Vehicle (UAV)
- Wingspan: 3.8m
- Altitude: 5 km
- Maximum take-off weight: 30kg
- Payload 15kg including fuel

Modularity

Module M1: Core module and data acquisition
Module M2: Meteorology
Module M3: Radiation
Module M4: Aerosol/cloud droplet
Module M5: Nano-sensors (Atm. Chem.)
Module M6: Topography
Module M7: Spectral imaging
Module M8: Radio Frequency Sounding
APAESO

Sensors, Imagers and Data Acquisition System will be designed in a modular fashion in order to allow easy interchangeability between modules (M1-M8) for the different missions and applications.

CONCEPT OF OPERATION

- The use of a dedicated autopilot will enable fully autonomous flights for the Cruiser.
- A Data Acquisition System (DAS) will be designed to provide fast and reliable data acquisition from the various sensors and imagers.
- Synchronized flight plans of multiple UAVs will enable multi-dimensional data acquisition.
- A Ground Control Station will have uninterrupted communication with the UAVs.

Applications (Examples)

Application name	Objectives (examples)	Instruments/ measurements
Meteorological measurements	Boundary Layer studies (Reuder et al., 2008)	Temperature (T), Relative Humidity (RH), Pressure (P)
Remote sensing - Earth surface observations	land and ocean surface properties, vegetation and land-use properties, archeological studies (Rango et al., 2009; Chiabrando et al., 2009)	RH, P, T, Radiometer, Hyperspectral camera, Infrared (IR) Imaging , Visual Imaging
Aerosol & Cloud measurements	Aerosol-Cloud Interactions (Roberts et al., 2008)	RH, P, T, Cloud Droplet Probe, Optical Particle Counter
Aerosol and Radiation measurements	Aerosol direct & indirect effects on climate (Corrigan et al., 2008)	RH, P, T, Optical Particle Counter, Albedometer
Aerosol sampling	Ice Nuclei, Cloud Condensation Nuclei, bio-aerosol sampling (Techi et al., 2010)	RH, P, T, Aerosol inlet, IN sampler, impactors

Imaging Sensors

Sauran Medieval Archaeological Complex in South Kazakhstan (source: http://www.transsoviana.org/13/smagulov-sauran.php)

Airborne image of pine trees and juniper bushes. Classification map (top) - Real color (bottom) Juniper (green) and Pine (red); source: http://www.resonon.com/airborne.html)

Thermal ortho-mosaic obtained from a UAV over a peach orchard. The top image shows the water stressed trees (warmer, in red and yellow) as compared with the fully irrigated trees (blue). The bottom image shows a low-altitude image where within-crown thermal variability is observed. (Berni et al. 2009)

References

Berni et al., IEEE Trans. Geo. Rem. Sensing, 47, 3, 722–738, 2009.
Chiabrando et al., Proc. of SPIE Vol. 7478, 747807, 2009
Corrigan et al., Atmos. Chem. Phys., 8, 737–747, 2008.
Rango et al., J. App. Rem. Sensing, Vol. 3, 033542, 2009.
Reuder et al., Met. Zeitschrift, Vol. 18, No. 2, 141-147, 2009.
Robert et al., PNAS, V. 105, 21, 7370–7375, 2008.
Techi et al., J. Field Robotics, 1–9, 2010.

Acknowledgement: The APAESO project is being supported by a grant of the Research Promotion Foundation Cyprus

Research Promotion Foundation

The Cyprus Institute

EEWRC