Content of the Presentation

- Israel experience with space systems.
- The JV company for Micro-Satellites.
- The Micro-Satellite markets and applications
- Aerial Launching.
- Mission-On-Demand (MOD)
- Some commercial remarks.
- Conclusions.
Israel Experience with Space Systems
The Beginning

On October 1988 Israel has launched its first satellite, Ofeq-1, by its own launch vehicle, the Shavit.

By that, Israel has become the 8th Space Power, after USSR, USA, France, Japan, China, UK, and India.
The Israeli Heritage in Space

**Already Launched**
- Oct. 1988 – Ofeq-1
- Apr. 1990 – Ofeq-2
- Apr. 1995 – Ofeq-3
- Feb. 1996 – TechSat-2
- May 1996 – AMOS-1
- Dec. 2000 – EROS A
- May 2002 – Ofeq-5
- Apr. 2006 - EROS-B
- Jan. 2007 - Ofeq-7
- Jan. 2008 - TECSAR-1
- Apr. 2008 - AMOS-3

**To Be Launched**
- TECSAR-2 – 2009
- EROS-C - 2009
- Venµs - 2010
- TECSAR-3 - 2011
- AMOS-4 - 2012
- EROS-D – 2011
- AMOS-5 – 2014
- Micro-Satellites – from 2010
The Israeli Space Products
The Main Space Industry in Israel

Elbit Systems

- EL-OP

ISI

- RS Operator

Spacecom

- AMOS Operator

IAI

- MLM Division
- ELTA Division
- TAMAM Division
- MBT Space Division

MicroSat

- AOCS Flight Equipment

RAFAEL

- MANOR Division

Elbit Systems

- Cameras

SAR & Comm P/L

AOCS Flight Equipment

LEO & GEO Satellites, Ground Stations

Space Propulsion, Composite

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The JV Company for Micro-Satellites

MicroSat-Israel ("MSI")
The Identification of the Problem in Space business

- Over the last eight years space systems launched by the US have cost an average of $2.5 billion.
- No one knows the average time, but it’s certainly approaching the decade, if not more.
- That’s too much and too long and fixing it is going to require that we truly work hard to fundamentally change the way we do business in space.
The Key Characteristics of Responsive Mission

- **Responsive** – Provide required information on time.
- **Flexible** – Provide multiple types of data (from different satellites).
- **Low Cost** – Total mission cost > 20 M$/spacecraft.
- **Short duration** – 6 months to 2 years mission life.
- **Small spacecraft** – Total mass < 500 lbs.
- **Single Function** – 1 payload per spacecraft.
- **Law Altitude** – 200 – 400 Km (allows small payloads to provide better performance).
Traditional vs. Responsive Space Mission

Traditional Space Missions
- Inherently strategic
- Global coverage, well known to the enemy
- Long term (20–25 year planning and implementation cycle)
- Expensive ($100M–$2B)
- Development cycles often >10 years
- Launch is unrelated to world events
- Does not respond well to changing events or circumstances
- No way to replace failed assets in a timely manner
- Data may or may not get to the end user in a timely manner

Responsive Space
- Tactical
- Focused coverage that can’t be predicted
  — Improved local coverage
- Near term (2–3 year planning and development cycle)
- Low Cost (<$20M recurring cost/mission)
- Launch in response to world events or immediate needs
- Can respond to world events, system failures, and changing circumstances
- Takes maximum advantage of new and evolving technology
- Immediately reconstitute failed assets
- Data delivered to the end user nearly immediately in a form that they can use

Our goal is not to replace traditional missions, but supplement them to give the warfighter an expanded set of tools that are flexible, responsive, low cost, and immediately available.
Main Drivers to the Creation of MicroSat

Tactical Space

Responsive Space

Small Nations Space Systems

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The Vision

- MicroSat-Israel Vision calls for many satellites working together in **constellations or formation** on low earth orbit, providing **continuous** target coverage.

- Some of the satellites would be **launched on demand** from military or civilian aircrafts and will be placed in optimal and focused orbits.

- The platforms will be **Micro Satellites**.

- Among other aspects, civil and defense needs and the relevancy of emerging technologies to the realization of this vision.
Applications for Micro-Satellite Systems

- Satellite-to-satellite observation.
- Satellite-to-launcher observation.
- Satellite-to-satellite maintenance.
- GPS Augmentation.
- Demonstrators.
- Asset tracking.
- Meter reading.
- **Telecommunications:**
  - Store & Foreword.
  - Mobile.
  - IP router.
  - Spectrum monitoring.
- **Earth observation:**
  - Complementary to military “Big-Bird”.
  - Agricultural monitoring.
  - Vegetation monitoring.
  - Disaster monitoring.
  - Terrain mapping.
  - Urban Planning.
  - Weather monitoring.
- Surveillance and signal intelligence.
- Space science (many applications).
- Formation flying.
- Space engagement and targeting.
- ....
To provide **affordable** space systems based on powerful micro-satellites, which will meet the “**Responsive Space**” requirements.

The system’s design shall be based on **missile technologies** already developed and implemented by **Rafael** and **IAI**.

The systems shall be used by the **military**, the **civilian** and the **commercial** markets.

The satellite shall be used also for “**Mission-on-Demand**”.

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SatLight – The Innovation
Low Cost Tactical Observation Microsatellite

CMOS matrix detector

High resolution within small dimension optics

Low altitude

Drag

Low cross section, elongated shape

Aerodynamic perturbation

Line of sight separated from satellite motion

Small satellite
SatLight – High-Lights

- Capabilities:
  - Low altitude Earth Observation micro-satellite (250-300 km).
  - Advanced novel electro-optical payload with day and night capability.
  - High resolution.
  - Mission Life: 3-4 years for regular mission, up to 6 months for MOD.
  - Can be used as stand alone satellite or as constellation of several satellites.

- Can be used for other applications.
SatLight Constellation

- Circular orbits;
- Altitude – 300 km
- Inclination – as required
- Walker type constellation

Need about 12-14 microsatellites in 4-7 orbital planes to satisfy the requirements
The Technical Innovation

- Low-cost design (use of COTS components, reduced redundancy)
- System engineering
- Light electro optical payload
- Use of scene matching for attitude control
- Image processing for automatic tracking of changes
- Intersatellite and satellite-to-ground laser communication
- MEOMS technology
- Light structures
- Compatibility to air-launch

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State-of-the Art Technologies and Capabilities

Technologies:

- Astrodynamics
- Formation flying technologies
- Inter-satellites laser communication
- High performance electro-optical systems
- Image processing
- Guidance and control
- Terminal and vision-based guidance
- MEOMS products and infrastructure
- Miniaturized communication products
- Space propulsion system
- Composite material space products

Capabilities:

- Space system engineering.
- Low cost design.
- Light structures design & manufacturing.
- Space electronics and electro-mechanic.
- Space power systems
- Satellite integration and test.
- Constellation design & implementation.
- Satellite in-orbit monitoring & control.
- Space product assurance.
- Space software design.
- Launch and orbit insertion.
Formation Flying

Allows to distribute payloads and to make use of the distance among them for large effective aperture.
Satellite Laser Communication

- Establishing fast 2.5 Gb/s, High quality, Bidirectional Communication Laser Link - Bit Error Rate (BER) $10^{-10}$ bit/s

- Implying Transponder type Accurate Ranging better than 10 cm, independent of range between terminals.

- Demonstrating a compact light weight (less than 4 kg on gimbals) ground system with high accuracy pointing & tracking capability to achieve the above communication link
Electric Propulsion

- **Hall Effect Thruster.**
- **Power Range** 250-450 W
- **Thrust Range** 10 - 25 mN
- $I_{sp} = 1450$ sec at 300 W.

Vacuum Firing
Multi-Spectral Mapping

Chlorophyll indicates pollution

Sediments originated from the Nile Delta

Nile Delta

EGYPT

ISRAEL

Chlorophyll [mg/m²]
Light Structures Design & Manufacturing

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How Micro-Satellites are launched today?

- Piggyback on heavy launch vehicle.
- Multiple launch on small/Medium launch vehicle.

*As of today there is no launch vehicle in the market dedicated to launch micro-satellites.*
Aerial Launching
Overview

- The size and weight of micro satellites is ideal for air launching.

- The air launching alternative has the following major advantages over ground launch:
  - By launching the satellites in high altitude we can increase the efficiency of the launch (by a factor of two) due to lower air density.
  - The cost of aerial launch and micro satellite can be very attractive and bring us closer to achieving the goal of “affordable space”.
  - Air launch enables rapid deployment of satellite into specific desirable orbit. The limitations of ground launch – such as launch window – are almost eliminates.
  - Reduce safety risks.
F-15

- Operational – Self Defence
- Unique side-by-side rocket booster solution
Gulf Stream - 550

Range: 12000 km
Ceiling: 51000 ft
The study included:
- Technical feasibility
- Performance
- Safety analysis
- Programmatic issues

The study covers insertion of payloads at the mass range of 30 to 460 kg to low LEO at the altitude range of 250 to 400 km
Mission on Demand Concept

- Micro-satellite (platforms + different payloads) to be manufactured to storage.
- Aerial launchers stages to be manufactured to storage.
- Upon request, and within short time (hours):
  - Satellite integration.
  - Launcher integration
  - Satellite and launcher mating and final check-out.
  - Launcher assembly on aircraft.
  - Take-off, flight, and launch.
MOD Advantages

- Launching the satellite when the event asks for it:
  - The ability to optimize the orbit for the specific mission until very short time before launch.
  - This optimization might reduce the number of the satellites needed to provide coverage of specific areas on the ground.
  - The PAYLOAD of the satellite can be changed and replaced until hours before the launch, providing more flexibility for the space architecture managers.
  - Modifications in the mission planning can be made ON ORBIT, by using various programs stored in advance in the satellite’s computer, or transmitted to it by the ground station.
Innovation Aspects in MOD

- Design the overall system (satellite platform, payload and launch vehicle) for rapid integration and readiness within hours.
- Design the satellite platform as plug-and-play for several types of payloads.
- Design the system to be able to change the mission on orbit.
- Etc.
Overview on Micro-Satellite Market

- **Definition**: Satellite with launch weight less than 120 kg.
- Since 1957 till 2007 year end, 524 micro-satellites were launched out of total ~3,000 earth orbit satellites (17%).
- 38 micro-satellites were launched in 2006.
- 26 micro-satellites were launched during January-July 2007.
- The Micro-Satellite is not expensive compared with large satellites.

In the near future market segment will expand due to:
- Very **responsive** to the users.
- **High performance** due to state-of-the-art technologies developed in the commercial electronic market: cell-phones, palm computers, etc.
- **Short time to orbit**.
The Non-Recurrent & Recurrent Cost

- Demonstration program of SatLight: ~50 - 60 M$.
- Demonstration program of aerial launcher: ~ 80 – 100 M$.
- Recurrent cost of aerial launcher: 2 – 5 M$.
- Recurrent cost of SatLight: 7 – 10 M$.

**It means that we will be able to put a satellite on orbit with cost of 9 – 15 M$. Such achievement has never met!!!**

**Assuming that these two demonstration programs will start in 2008, MicroSat can be in the market during 2010.**
Our Forecast

- **The micro-satellite market will expand dramatically in the coming years, especially with the realization of the MOD.**

- **Forecasts show an average of 50-75 microsatellite launches per year in the next decade.**

- **Our forecast shows growing market as the responsive space and MOD concepts will penetrate to the market.**
Two main market segments are foreseen:

- **The well developed countries** that are looking for responsive missions based on small and smart satellites. We offer high performance micro-satellite constellations (or formations) carrying variety of payloads serving the military, civilian and commercial organizations.

- **The developing countries** that wish to enter to the space market by launching their own satellite as a mean of upgrading the local industries and the academic institutes. We offer initiate a Project, managed by us and financed by the government. Know how transfer will allow local companies to participate in the Project.
Conclusions
Conclusions

- The innovation and state-of-the-art technologies in the area of micro-satellites and aerial launcher has been demonstrated.
- We are convinced that tactical space missions, based on micro-satellites and MOD have an important place in the space missions in the near future for dual use applications (military and civilian/commercial).
- Launch on Demand can be achieved by air launch systems, and will bring us closer to real responsive space capability.
- International cooperation is an important factor in developing responsive space capabilities, based on modern and high performance microsatellite platforms.
Levels of cooperation

- Buy and operate a micro-satellite system (single micro-satellite or constellation/formation of micro-satellites)
- Participating in the R&D and manufacturing of the proposed micro-satellite system.
- Support the marketing activities of MicroSat-Israel in Latin America (and other markets) towards developed and developing countries.
- Become a share holder of MicroSat Israel.