Council for Space x ICT
Ministry of Internal Affairs & Communications

ICT Business with Micro/Mini-Satellites

Professor Sir Martin Sweeting FRS FREng
Executive Chairman SSTL

25th January Tokyo
Small satellites are not new but, since the early 1980’s, they have evolved steadily in their capabilities and most importantly their utility – to the point where, in the last few years, they have provided both lower cost and more responsive solutions to meet many well-trodden applications whilst also stimulating completely new business models.

This has fundamentally changed the economics of space ... for both the civil and the security/defence sectors.

Key characteristics:

- Physically small
- Low cost of manufacture & launch
- Rapid development and build
- Use of up-to-date technology (‘COTS’)
- An ‘IT’ management approach – innovative & agile small teams
- Flexible orbital operations
Small satellites

The underlying technologies that have enabled this ‘peaceful revolution’ have come from the enormous investments made by the industrial and domestic consumer sectors.

These have created mass markets for their products ... reducing the unit production costs by orders of magnitude whilst at the same time achieving high yield and reliability through a parallel revolution in manufacturing & production techniques.

So far, the evolution of small satellites has been driven primarily by advances in microelectronics, whilst the structural designs have remained based largely on conventional techniques.
Small satellites

Different applications need different capabilities

Countries operating small satellites

Brought access to space within reach of every nation, smaller organisations & businesses
Small satellite constellations

The lower unit cost of small satellites has made constellations economically practical - primarily in low Earth orbit.

The first applications were for digital store-&-forward communications in the 1990’s (before www) e.g. HealthSat, Orbcomm, Iridium, Globalstar

Optical Earth Observation from smallsats took longer to become operational, from around 2005, but now provide high resolution pan, m/s & video
Small satellite constellations

Many new initiatives have emerged, enabled by the rapidly maturing Smallsat technologies:

- Ship & Aircraft tracking
- Smart cities, agriculture, pollution management
- M-2-M digital communications
- Responsive disaster monitoring & management
Terrestrial digital connectivity

Large population areas not served by high-speed digital services

Global digital connectivity

Traditional GEO SAT communications well established
- Overlay to fibre
- Remote region service
- DTH broadcast and broadband internet connectivity

Big GEO satellites are getting BIGGER!
- Higher power – smaller ground terminals
- $/MHz/Mbps capacity efficiency

Appetite for smaller GEO satellites
- Reduce capital investment for start-up services
- Service augmentation
- Frequency filing

Advantages
- Wide regional coverage
- Simple ground terminals

Disadvantages
- Costly launch
- Latency – becoming critical for some digital applications
- High radiation environment
LEO communications constellations

New business models enabled by small satellite development

- Low unit cost
- Constellations (10-100-1000’s)
- Multiple launch requirement stimulating launcher market
- Unique solution for financial markets
  (ΔmS advantage wrt Fibre)
- Global coverage possible (incl. high latitudes)

Questions...

- Constellation capital cost?
- Launch costs - $/kg?
- Business plan - revenues/cost (RoI)?
- Launcher capacity?

Advantages

- Link budget – smaller terminals
- Low latency
- Resilience to failures
- More launch options
- Frequency reuse
- High latitude coverage

Disadvantages

- Many satellites needed
- Agile beams – hand-over
- Inter-satellite links
- Battery cycles / doppler
Small satellite market

Totals launched
separating commercial constellations

- EO constellations
- LEOCOMMS
- Nano
- Micro
- Mini
- >500kg

Growth Areas
- LEO, EO/comms
- Cubesats / Nanosats

SmallSat
BigSat
Small satellite constellations

Number of Proposed Systems
of commercial satellite constellations

- LEOcomms
- Hires optical
- Meteo
- Science
- Medium resolution
- m2m comms
- Radar
- Intersat
- Tracking
- Hires optical and video
- Microgravity
- Interference
- Mixed
- MEOcomms
- Hyperspectral
- Infrared
- Lunar comms

Comms (& science)
EO

68 in total
Small satellite communications constellations

<table>
<thead>
<tr>
<th>System</th>
<th>#satellites</th>
<th>Mass class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iridium (voice+data)</td>
<td>Gen 1: 93 (late 1990’s) Gen 2: 66</td>
<td>700→ 860kg</td>
</tr>
<tr>
<td>GlobalStar (voice+data)</td>
<td>Gen 1: 72 (late 1990’s) Gen 2: being deployed now</td>
<td>480→ 700kg</td>
</tr>
<tr>
<td>Orbcomm (M2M)</td>
<td>Gen 1: 32 (+6) current Gen 2: 19</td>
<td>50 → 150kg</td>
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</table>

<table>
<thead>
<tr>
<th>System</th>
<th>#satellites</th>
<th>Mass class</th>
</tr>
</thead>
<tbody>
<tr>
<td>OneWeb</td>
<td>648</td>
<td>&lt;200kg</td>
</tr>
<tr>
<td>Boeing</td>
<td>3000</td>
<td>“small”</td>
</tr>
<tr>
<td>Samsung</td>
<td>4600</td>
<td>“small”</td>
</tr>
<tr>
<td>SpaceX STEAM</td>
<td>4000</td>
<td>200-300kg</td>
</tr>
<tr>
<td>LEOSAT</td>
<td>80-140</td>
<td>“small”</td>
</tr>
</tbody>
</table>
Small satellite constellations

~19 systems proposed comprising over 10,000 satellites

<table>
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<tr>
<th>System</th>
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<th>Mass class</th>
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<tbody>
<tr>
<td>SkyFi</td>
<td>60</td>
<td>&lt;10kg</td>
</tr>
<tr>
<td>Outernet</td>
<td>100</td>
<td>&lt;10kg</td>
</tr>
<tr>
<td>Yaliniy</td>
<td>135</td>
<td></td>
</tr>
<tr>
<td>Sky Space and Global</td>
<td>200</td>
<td>&lt;10kg</td>
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<tr>
<td>Blink Astro</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>80LEO</td>
<td>288</td>
<td>~150kg</td>
</tr>
<tr>
<td>Commstellation</td>
<td>Up to 800</td>
<td>~150kg</td>
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<tr>
<td>Kepler communications</td>
<td>?</td>
<td>&lt;10kg</td>
</tr>
<tr>
<td>Audacy</td>
<td>200</td>
<td>&lt;10kg</td>
</tr>
<tr>
<td>...</td>
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Addressing a range of applications including IOT, M2M, etc.
Small satellite business models

Non-traditional (space) business models
Venture capital, Public Private Partnerships
IT business models
High development pace – technology freshness
Focus on applications and end-users
CLOUD storage and computing
Web-based services
Crowd-funding
Ardusat / Nanosatisfy and Skycube satellites launched

Coming soon…
- Optical inter-sat and sat-gnd data links
- Quantum key distribution

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<tr>
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<th>Mass class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laserlight</td>
<td>12</td>
<td>?</td>
</tr>
<tr>
<td>BridgeSat</td>
<td>50</td>
<td>150kg</td>
</tr>
<tr>
<td>SpaceBelt</td>
<td>16</td>
<td>?</td>
</tr>
<tr>
<td>...</td>
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</table>
Small satellite business

Number of Satellites
as part of proposed commercial satellite constellations

Oct 2016

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Satellites</th>
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<tbody>
<tr>
<td>Tracking</td>
<td>59</td>
</tr>
<tr>
<td>Various</td>
<td>329</td>
</tr>
<tr>
<td>EO</td>
<td>1312</td>
</tr>
<tr>
<td>Comms</td>
<td>13517</td>
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</tbody>
</table>

Comms: 14,000
EO: 13,517
Various: 329
Tracking: 59

0 2000 4000 6000 8000 10000 12000 14000 16000
In the last 5 years the pace of microelectronics development has continued to accelerate – much in line still with the observation in the 1960’s by Gordon Moore.

But... there has been a parallel development in new materials combined with robotics that have given rise to new satellite/spacecraft manufacturing techniques that enhance small satellite capabilities but also further reduce cost and timescale.

Robotic additive (and subtractive) manufacturing techniques now make possible product geometries that were previously physically impossible by human hands.

Digital manufacturing provides freedom of location and dramatically increased speed of the design evolution and the product innovation cycle.
Increasingly large apertures are needed in space for astronomical, EO and Comms applications. These can only be achieved through in-orbit robotic assembly.

**UK-US ARReST demonstration project**

*Autonomous Assembly of Large Aperture Space Telescopes Using Multiple Deformable Mirror Elements...*
Small satellite constellations

These factors have come together to stimulate new innovative space system proposals – taking advantage of the design agility, low unit cost and rapid manufacturing delivery to make constellations of 100’s, even 1000’s, of small satellites practical that could enable new infrastructures providing ubiquitous access to high speed digital communications and unparalleled persistence of global Earth observation.

At the same time, the growth of the various terrestrial communications infrastructures and advances in data handling, management and knowledge extraction – often referred to as ‘Big Data’ – have blurred the boundaries between space and terrestrial systems.

Synergy of space & terrestrial systems leading to ad-hoc communications networks
Small satellite constellations

These new ‘mega’ constellations also pose additional challenges

• regular, affordable launch on a tempo hitherto not achieved
• space traffic management and debris control
• the efficient handling communication of vast amounts of data
• safe autonomous orbital operations
• communications spectrum and legal or policy issues.

However, like the extraordinary number and diversity of ‘SmartPhone Apps’ that have been created by a completely new business community, most of which we would not have dreamed of a decade ago, it is probable that the new smallsats and constellations will stimulate applications that we currently do not envisage
Orbital debris and small satellites

Space debris is a issue for all of the space community.

Widespread misconception that only satellites are major contributors
- Key contributors to the debris problem are defunct upper stages & large satellites
- Small satellites rarely carry pressure tanks, pyro devices or other energetic systems
- Cubesats are predominantly launched in orbits with lifetimes much less than the recommended 25 years
- 100 Cubesats have the same cross sectional area as a typical 500kg satellite
- The key issue is actually tracking and manoeuvrability
- Mega-constellations also introduce space systems not previously considered in debris population modelling.

We expect the small satellite community to come up with technologies and solutions
- Clean-up missions with capture technologies.
- De-orbit technologies, including tethers, sails, electric propulsion
- Operator assisted tracking, beacons and retroreflectors?

http://www.spacenews.com/article/opinion/42329another-view-on-cubesats-and-debris
https://www.planet.com/pulse/keeping-space-clean-responsible-satellite-fleet-operations/?utm_content=buffera312c
What does this mean for exploration?

Small satellite techniques

- Will not replace the ‘hi-fi’ science observatories and missions
- Can provide complimentary science – increased temporal/spatial measurements
- Support the exploration infrastructure – communications & navigation/timing
- Increase tempo of focussed exploration
- Encourage a reduction in overall cost
- Provide opportunities for wider global participation in exploration – public/private
- Introduce a ‘commercial’ element into exploration - exploitation
Conclusions

We have seen an unprecedented investment in the industry in the last few years

We have never built or planned to build so many “small” satellites

Commercial ventures are redefining what space can offer the users

New applications, new business models, new challenges

Small satellites tending to optimise for size & capability

BUT...

• Remember IRIDIUM & GLOBALSTAR
• Huge investments
• Return on investment expected by investors
• Expect consolidation