Distributed Satellite Systems
a national SME-led technology roadmap for small satellite technologies

SPACEPLAN2020 – an SME-led roadmap for small satellites
Contents

• ISIS as an Small Systems Integrator
• DSS Background and history
• Scope and definition
• Objectives and ambitions
• Market outlook
• Relation to other roadmaps
• Key technology themes
• Roadmap outline
• Programmes and projects
• Near-future activities
• Conclusions
ISIS – Innovative Solutions In Space

(Very Small) System Integration Activities
ISIS group - overview

- Founded in 2006, spin-off from Delfi-C3 project
- Currently about 50 staff (FTE)
- Provider of small satellite products and services
- Vertically integrated small satellite company
- Offices in Delft, The Netherlands and Somerset West, South Africa
- 2013 highlights:
  - Triton-1 Satellite for SAT-AIS successfully launched
  - Responsible for launch 11% of all satellites in 2013
  - Record sales to 6 continents
People at ISIS

- 50 FTE
- 45% international
  - 20 Nationalities
  - 12+ languages

Age of Employees

- > 65
- 55-65
- 45-55
- 35-45
- 25-35
- < 25

No. of Employees
Capabilities and competencies

Systems Engineering
Radio Frequency Engineering
Attitude Control Engineering
Embedded Software

MAIV Expertise
Electrical Engineering
Mechanical Engineering
Flight Software Engineering
Main Activities

Products
- CubeSat Avionics
  - Radios
  - Antennas
  - Solar Arrays
  - OBCs
  - Etc.
- Ground Stations
- Operations Centers
- Support equipment
- Software Tools
- Both standardized and custom developments

Launches
- Launch Services
  - DNEPR
  - Soyuz
  - Long March
  - VEGA
  - ANTARES
  - Falcon-9
  - PSLV
- Piggy back
  - CubeSats
  - Nanosats
  - Microsats
- Associated Services
  - Testing
  - Insurance

Missions
- Turn key solutions
  - CubeSat platforms
  - Payloads
  - Ground segment
  - Launch
  - Operations
- Fast implementation times
- Including training, knowledge transfer and co-development

Applications
- Based on satellite networks
  - Radio Astronomy
  - Maritime Monitoring
  - Agriculture
  - Communications
- Global Coverage
- High revisit times
- Fully integrated solutions
ISILaunch Launch Services

INNOVATIVE SPACE LOGISTICS BV

ISILaunch Services

CubeSat
Cluster Launches

Nanosatellites

Microsatellites

Other Payloads

Launch Adapters

Test Services

Launch Insurance

ISILaunch

PSLV-C14

ESTCube

ISILaunch B2
DNEPR – November 2013
QuadPack Launch Solution: the future

1 single CubeSat launch interface for all variants and all LV’s

Supports range of satellites
- 1-Unit CubeSat
- 2-Unit CubeSat
- 3Unit CubeSat
- 6-Unit CubeSat
- 12-Unit CubeSat

Customized versions possible

Includes deployment sequencing
End-to-end small satellite solutions:
- Small satellite systems and components
- Capable nanosatellite platforms
- Launch services for auxiliary payloads
- Ground stations and mission operations
- Integrated space applications
**Platform Specifications**
Mass: 2 -3 kg  
Power: 5W peak, 3W AOP  
Downlink: 10 kbps  
Pointing knowledge: < 5°  
Pointing Accuracy: <10°  
Orbit determination: -  
Propulsion: -  
Cost: 200 – 400 k€  

**Payload Accommodation**
Mass: 1 kg  
Power: 4W peak, 1,5W AOP  
Data Storage: > 2 Gbit  

**Possible Payloads**
Small camera  
Technology demonstrator  
Space Weather  

**Launch Options**
Dispenser: ISIPOD  
Cost: 125 - 175 k€  

**ISIS 2-Unit CubeSat Platform**
First CubeSat Mission Capability
**Platform Specifications**
- Total mass: 4 kg
- Power: 20W peak, 10W AOP
- Downlink: 100-1000 kbps
- Pointing knowledge: < 0.1°
- Pointing Accuracy: <1.0°
- Orbit determination: GPS
- Propulsion: -
- Cost: 400 – 600 k€

**Payload Accommodation**
- Mass: 1-2 kg
- Power: 20W peak, 10W AOP
- Data Storage: > 20Gbit

**Possible Payloads**
- SAT-AIS receiver
- Science payload
- Mid-resolution imagers

**Launch Options**
- Dispenser: 3U ISIPOD / QP
- Cost: 175-200 k€

**ISIS 3-Unit CubeSat Platform**

Low cost operational missions
**Platform Specifications**
- Mass: 15-20 kg
- Power: 25W peak, 15W AOP
- Downlink: 1-10 Mbps
- Pointing knowledge: < 0.05°
- Pointing Accuracy: < 0.2°
- Orbit determination: GPS
- Propulsion: Optional
- Cost: 500 – 1000 k€

**Payload Accommodation**
- Mass: 5-10 kg
- Power: 20W peak, 10W AOP
- Data Storage: > 100 Gbit

**Possible Payloads**
- Thermal Infrared Imager
- Multispectral imagers
- Science payload
- Mid-resolution imagers

**Launch Options**
- Dispenser: 12U Quadpack
- Cost: ~500 k€

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**ISIS 12-Unit CubeSat Platform**
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Operational remote sensing mission
Global vessel traffic data using spacebased sensors:

- Near-realtime data using dynamic AIS messages
- Data access based on subscription
- Proprietary spacebased AIS receiver technology
- Cost effective nanosatellite constellation

IDS - Innovative Data Services BV is an ISUS company.
Problem: Vessel whereabouts

Vessel tracking issue:
- Near shore only
- Limited coverage
- Cooperating vessels

Growing need:
- Cargo Owners
- Supply chain
- Logistics
- Monitoring
- Enforcement
- Services
- Safety

Applicable to:
- 100,000+ large vessels (>300GT)
- % of the 4,000,000+ fishing vessels
A brief history on the DSS roadmap

- 2004 – Space Action Plan – Small satellites as an incubator topic (kraamkamer)
- 2005 – BSIK MicroNed MiSAT project – Resulting in NL nanosatellite activities
- 2010 – ASSYS - OLFAR STW project
- 2011 – FES DCIS start, QB50 start, NanoSpace Initiative
- 2012 – Roadmap Satellite Cluster Technology – incubator topic (kraamkamer roadmap)
- 2013 – Distributed Satellite Systems study

- 2013: Merged into Distributed Satellite Systems roadmap
Definition of Distributed Satellite Systems

- A space system consisting of multiple space elements that can communicate, coordinate and interact in order to achieve a common goal.
  - Concurrency of elements
  - Tolerance for failure of individual systems
  - Scalability and flexibility in design and deployment of system

- Complementary to large singular space systems

- Current Focus:
  - Nano- & microsatellites
  - Upstream value chain
National DSS Stakeholders

13 SME’s (incl. Coordinator)
8 Research institutes
3 Large companies

3-Mar-14 SPACEPLAN2020 – an SME-led roadmap for small satellites
Ambitions and Objectives

- Use this niche-market to move towards a significant system level industrial base (from a laboratory to a factory).
- A leading role in the development of key know-how and technology for distributed satellite systems based on very small satellites.
- Maintain and expand the extensive system level expertise to develop, implement and operate distributed satellite systems, by the realisation of real missions and systems.
- Establish a leading global position (top-3) as a system integrator for civil distributed satellite systems.
- To use the technological base for distributed satellite systems to serve a variety of downstream markets and applications, in which a large part of the value chain is served by Dutch entities.
DSS - a global market
Market build-up

Roadmap Focus
Research
Product development
Products and services
Turnkey solutions
Apps

Downstream Market
Upstream Market
Exponential growth in the nanosatellite market: DSS
Constellations, swarms, etc are on the rise

### Nano/Microsatellite Future Program Summary (1-50 kg)

<table>
<thead>
<tr>
<th>Name of Program</th>
<th>Time</th>
<th>Organization</th>
<th>Country</th>
<th>Mass (kg)</th>
<th>No. Launched</th>
<th>Total Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>NSF Geospace &amp; Atmospheric CubeSat</td>
<td>2010-2015</td>
<td>NSF</td>
<td>USA</td>
<td>1-3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>NASA EDSN</td>
<td>2013-2014</td>
<td>NASA Ames Research Center</td>
<td>USA</td>
<td>3</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>NASA CubeSat Launch Initiative</td>
<td>2011-2014</td>
<td>NASA</td>
<td>USA</td>
<td>1-8</td>
<td>13</td>
<td>71</td>
</tr>
<tr>
<td>F6</td>
<td>2015</td>
<td>DARPA</td>
<td>USA</td>
<td>45</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>SeeMe and ALASA payloads</td>
<td>2014-2015</td>
<td>DARPA</td>
<td>USA</td>
<td>45</td>
<td>0</td>
<td>36</td>
</tr>
<tr>
<td>NRO Colony I &amp; II</td>
<td>2010-2016</td>
<td>NRO</td>
<td>USA</td>
<td>3-5</td>
<td>4</td>
<td>62</td>
</tr>
<tr>
<td>QB50</td>
<td>2015</td>
<td>Von Karman Institute / Various</td>
<td>Various</td>
<td>2</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>HUMSAT</td>
<td>2013-2014</td>
<td>University of Vigo / Various</td>
<td>Various</td>
<td>1</td>
<td>0</td>
<td>10</td>
</tr>
</tbody>
</table>

#### Large Program Breakdown for Announced Future Launches

- NSF EDSN
- NASA CSLI
- F6
- SeeMe
- NRO Colony
- QB50
- HUMSAT
- Other (U.S.)
- Other (Non-U.S.)

#### Announced Future Launches 2013-2015
DSS – an immature but promising market

- Shift in the market visible from single satellite project to satellite networks
- Different end-users (agencies, companies) drive development rather than the original educational market
- Many constellations, swarms, etc. in development
- At present (2013) mainly precursor satellites for later distributed satellite systems.

5 out of 14 spacecraft are (precursor) elements of a distributed satellite system.
### Institutional Market

- **EC FP7 / H2020:**
  - DSS: QB50 (50 spacecraft)
  - Technology demo projects
  - Debris, spin-in technologies
- **ESA:**
  - Technology Development
    - GSTP / TRP / ARTES
  - Applications
    - ARTES (S-AIS, S-ADS-B, VDE-SAT)
    - Earth Observation
- **NL Technology Programme:**
  - STW, FES, etc.
- **National Science Programme**
  - case-by-case
  - Science Mission (OLFAR)

### Commercial Market

- **Upstream Market**
  - Export driven (non-EU)
  - Components
  - Turnkey solutions
  - Launch market
- **Applications Market**
  - Emerging in EU and US
  - Size very dependent on case
  - Large VC investments in ’12/’13
- **Strong Growth: >> 30% / yr**
From technology to applications

2012-2013 Focus

2014 - 2015 Focus

Key Systems Elements

Distributed Satellite Systems

- Sustainable Access To Space
- Payload and mission support technologies
- Ensured Communications Capability

SPACEPLAN2020 – an SME-led roadmap for small satellites
Sustainable access to space

**Sustainable Access To Space**

<table>
<thead>
<tr>
<th>Launch access</th>
<th>Satellite Deployment Systems</th>
<th>End-of-life Solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nossatellite Launchers</td>
<td>Launch Vehicle Integration</td>
<td>Deorbit technologies</td>
</tr>
<tr>
<td>Launch Vehicle Integration</td>
<td>Cluster Delivery Systems</td>
<td>Debris removal technology</td>
</tr>
<tr>
<td>Adapters and Structures</td>
<td>Nanosatellite Dispensers</td>
<td>Space Situational Awareness</td>
</tr>
<tr>
<td>Nanosatellite Dispensers</td>
<td>Sequencing Electronics</td>
<td></td>
</tr>
</tbody>
</table>

- **Link with structures roadmap**
  - SPS systems (Dutch Space)
  - CubeSat dispensers (ISIS)

- **Constellation and swarm deployment strategies**
  - Deployment dynamics (ISIS, TUD)
  - Constellation build-up and maintenance (ISIS, TUD, Dutch Space)

- **Link with propulsion roadmap**
  - Deorbit motors (ISIS, TNO, APP)
  - Aerobrakes (ISIS, CGG)
  - Reentry strategies (TUD)

SPACEPLAN2020 – an SME-led roadmap for small satellites
Payload and mission support technology

- **Link with structures roadmap**
  - Deployable arrays (ISIS)

- **Link with AOCS roadmap(s)**
  - Sun sensors (Lens, MOOG-BE, TNO)
  - Star sensors (ISIS, Hyperion)
  - Reaction wheels (TUD, Hyperion, MOOG-BE)
  - AOCS System & algorithms (ISIS, Dutch Space, TUD)

- **Link with propulsion roadmap**
  - Electrical micropropulsion (TNO, SystematIC)
  - Coolgas systems (TNO, CGG, SystematIC)
  - Resistojets (TUD)

- **Link with processing roadmap**
  - Onboard processing (SSBV, NLR, ISIS)
Sustainable access to space

**Ensured Communications Capability**

<table>
<thead>
<tr>
<th>Ground Segment</th>
<th>Nanosat Radios</th>
<th>Nanosat Antennas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Automated operations</td>
<td>Global ground station network</td>
<td>Ensure Nanosat Spectrum</td>
</tr>
<tr>
<td></td>
<td>Inertial satellite communications</td>
<td>Agile Software Defined Radios</td>
</tr>
<tr>
<td></td>
<td>High Throughput Radios</td>
<td>Low freq deployable antennas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>High gain tracking antennas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(phased) arrays</td>
</tr>
</tbody>
</table>

- **Link with RF roadmap**
  - Spacecraft antenna design (ISIS, TUD, Utwente, TNO, NLR, SSBV)
  - Frontends (Lionix, Satrax, TNO, TUD, Utwente)
  - Processing (SSBV, NLR, TNO)
  - Beamforming (ASTRON, TUD, ISIS)
  - Intersatellite links (TNO, Utwente, TUD, ISIS)

- **Ground systems and antennas**
  - Automation and autonomy (ISIS, TUD, SSBV, CGI)
Roadmap Key Technology Elements

- Bulk market technology and reliability
- Software architecture
- Distributed processing
- Ad-hoc netwerking
- End-of-Life solutions
- AOCS
- Scalability
- Series-production
Roadmap
Outline for the roadmap DSS

• OLFAR as a long term goal, a complex mission to provide something on the horizon
Trackrecord, current and planned NL missions

- Technology development established
- Established position in the upstream market
Possible Future

- Precursors to applications
- First DSS applications established
- Expand upstream position
Take a flexible route for spin-in / spin-off

- Spin-in from non-space high tech markets
- Find mid-term markets for OLFAR technologies
Many markets identified
Temporal resolution driving
Other markets: GeoICT, ...

DSS downstream opportunities
• Most technology in development in TRL 4-6 stadium

• New projects aiming to bring technology up to TRL 5-6

• With OLFAR on the horizon, maturity is not yet an issue, but needs attention

• Whatever is ready, can be marketed in the upstream market and build heritage

• Steering of critical technology development by industry for spin/off applications
Current Projects and Programmes - National

- SPARCS - Intersatellite links – TNO - TUD
- Nanosat Reaction wheels – TNO – TUD - Hyperion
- NKS – DeOrbit Rocket Motor – APP – TNO – ISIS
- ADS-B – aircraft tracking payload – ISIS – NLR – TNO – SystematIC
- Small Imagers – Cosine – ISIS
- Distributed Remote sensing applications: ISIS - cosine
- High-data rate communication applications: ISIS
- SPS-1 - Launch structures for nanosatellites: ISIS – DutchSpace
- ...

3-Mar-14 SPACEPLAN2020 – an SME-led roadmap for small satellites
<table>
<thead>
<tr>
<th>Programme</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FP7 – DeOrbitSail – (ISIS)</td>
<td>End-of-life / comms</td>
</tr>
<tr>
<td>FP7 – QB50 – (ISIS, TU Delft)</td>
<td>Distributed In-situ Meas.</td>
</tr>
<tr>
<td>FP7 – PEASSS - (TNO, ISIS)</td>
<td>sensor stabilization</td>
</tr>
<tr>
<td>FP7 – Deploytech - (CGG, TNO)</td>
<td>inflatable structures</td>
</tr>
<tr>
<td>FP7 – Microtrust - (TNO, SystematIc)</td>
<td>propulsion</td>
</tr>
<tr>
<td>FP7 – SMESAT - (ISIS, SystematIc)</td>
<td>AOCS, power system</td>
</tr>
<tr>
<td>FP7 – Different - (ISIS)</td>
<td>Distributed Radar System</td>
</tr>
<tr>
<td>FP7 – Remove Debris - (ISIS)</td>
<td>Active Debris Removal</td>
</tr>
</tbody>
</table>
Programmes and Projects - ESA

- ESA – ARTES (ISIS)
  - Sat-AIS – Distributed System for tracking ships
    - Sensor development
    - System development
  - VDE-SAT study – Distributed System for VHF broadcast
- ESA - GSTP
  - CubeSat Technologies (ISIS)
    - CubeSat Star Sensors
    - High Speed Radios for CubeSats
What’s Next?

The Future

NEXT EXIT
Near-future Activities – 2014/2015

### NL Missions and Milestones

- **QB50**
  - Precursor Satellites (ISIS) – Q2 ‘14
  - DelfFI (TU Delft) – Q3 ‘15
  - QB50 main flight – Q3 ‘15

- **Sat-AIS Constellation**
  - TRITON-2 – Q3 ‘14
  - TRITON-3 & 4 development – Q1 ‘14

### Technology Projects & Programmes

- **H2020**
  - 2014: Spin-in Technologies
  - 2015: Fractionated Sensors, Debris

- **ESA**
  - GSTP:
    - CubeSat Technologies
    - IOV / IOD and access to space
  - ARTES:
    - Satellite AIS
    - Other Distributed Applications

- **National Programmes**
  - ASSYS – OLFAR (ongoing)
  - NANONext – DCIS (ongoing)
  - STW Valorisation Grant
  - STW Perspectief Programme
• Expand distributed payloads and applications
  – VDE-SAT
  – S-ADS-B
  – Distributed Radar
  – Remote Sensing
• Align with downstream roadmaps
• Align with top-tier-sectors:
  – Energy,
  – Logistics,
  – Water,
  – Agri&food
• Find champions and launching customers
Ecosystem approach: open innovation

Looking for disruptive business models

OLFAR as long term goal and guiding point

Aimed at maximizing spin-in / spin-off

Technology part reasonably well established

Now focus on instruments and application elements
Thank you for your attention!

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