NAVISP-E12-006
Development of a Spaceborne GNSS Receiver

NAVISP Industry Days
January 23, 2020
Dr. Cyril Botteron
Company overview

Syderal Swiss SA
- Date of creation: 1942 under the name of CIR
- Part of ALCATEL Space between 1998 & 2003
- SYDERAL SA since 2003: Management owned, Swiss SME
- 70 employees in Neuchâtel, Switzerland

Syderal Group
- Subsidiary in Poland: SYDERAL POLSKA → Space el.
- Subsidiary in Switzerland:
  - KEYCOM → Laundry/Building management system
- Total of ~90 employees

Background
- National leader in hardware and software electronic solutions for satellites
- Design and production of flight electronics for more than 25 years, 50 missions with 100% success

Full in-house production facility, ESA qualified
- 250 m² clean room
- Automatic pick & place and manual assembly / test
Company overview – Institutional market references

Data Handling

- EARTH CARE / SVM – Mass Memory and Formatting Unit
- GAIA / SVM – Payload Data Handling Unit
- EXPERT – Vehicle Memory Unit
- SAR LUPE – DCSU – Mass Memory board
- KOMPSAT 2 – DCSU – Mass Memory board
- SOHO / VIRGO – Data Acquisition System
- XMM / RGS – Data Acquisition System (incl. Formatting)

Instrument Controllers / Mechanism Drives

- FLEX - FLORIS Instrument Control Unit
- INSIGHT – Seismometer Electronics Box
- SENTINEL 1 / SES – Instrument Control Module
- AEOLUS – Aladin Control and Data Management Unit
- GOCE - Gradiometer complete electronics (3xFEEU, GAIEU & TCEU)
- IASI Ng – Mechanism Drive Electronics
- MTG / IRS – Interferometer Control Electronics
- BEPI-COLOMBO / BELA – Analogue Electronic Unit
Goal: development of a high performance, COTS based GNSS receiver targeting satellite constellations

- To Bridge gap between low-end and high-end solutions
- For single LEO spacecraft and large LEO constellations
- Competitive price to performance ratio
- Basis platform for future evolutions

Main project outcome:
- Engineering Model of NAVILEO receiver
NAVILEO receiver

Advantages
- Based on rad-tolerant architecture & COTS EEE components ⇔ low recurrent price, suitable for small/mini/micro sat & mega-constellations
- High sensitivity ⇔ supports both active & passive antennas
- Multi-constellation & multi-frequency ⇔ high PVT availability even in GEO, HEO,...; high accuracy (iono-free combination solution)
- Onboard orbital propagator ⇔ Improved PVT perfo., sensitivity and availability
- In-flight FW/SW upgradability ⇔ upgradable (new signals, constellations, ...)
- **Fugro Spacestar enabled** ⇔ Real-time sub-dm (3D rms) POD on-demand

Availability
- EM: Q2 2020
- FM Q4 2020

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**Performance characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>48</td>
</tr>
<tr>
<td>Antenna inputs</td>
<td>1 (2 in option); supports both active and passive antenna(s)</td>
</tr>
<tr>
<td>Signals and frequ.</td>
<td>Galileo E1b and E5a, GPS L1C/A and L5i/Q</td>
</tr>
<tr>
<td>Acquisition sensitivity (dBHz, for Pf=0.9)</td>
<td>28 (L1); 31 (E1b)</td>
</tr>
<tr>
<td>Tracking sensitivity (dBHz)</td>
<td>20 (L1, E5a); 22 (L5); 24 (E1B)</td>
</tr>
<tr>
<td>Warm / cold TTFF¹</td>
<td>&lt; 20 s / &lt; 100 s</td>
</tr>
<tr>
<td>Typical pos. accuracy¹</td>
<td>&lt; 5 m (3D rms)</td>
</tr>
<tr>
<td>PPS signal (RS-422)</td>
<td>&lt; 50 ns (rms)</td>
</tr>
<tr>
<td>TM/TC</td>
<td>UART, CAN in option (other interfaces possible). Fully compliant with PUS/CCSDS standard.</td>
</tr>
<tr>
<td>Update rate</td>
<td>1 - 10 Hz</td>
</tr>
</tbody>
</table>

**Physical characteristics (TBC)**

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power / voltage</td>
<td>8 W typical at 5 VDC</td>
</tr>
<tr>
<td>Mass</td>
<td>1300 gr</td>
</tr>
<tr>
<td>Dimension</td>
<td>219.5 x 110.5 x 59 mm³</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>-20°C - +50 °C</td>
</tr>
<tr>
<td>Lifetime</td>
<td>Min. 5 years in LEO</td>
</tr>
</tbody>
</table>

¹Tested in a typical LEO orbit, all SVs at 44 dB-Hz
**Advantages**

- Based on rad-tolerant architecture & COTS EEE components → low recurrent price, suitable for small/mini/micro sat & mega constellations
- High sensitivity → supports both active & passive antennas
- Multi constellation & multi frequency → high PVT availability even in GEO, HEO,…; high accuracy (iono-free combination solution)
- Onboard orbital propagator → improved PVT performance, sensitivity and availability
- In-flight FW/SW upgradability → upgradable (new signals, constellations, …)
- Fugro Spacestar enabled → Real-time sub-dm (3D rms) POD on demand

**Availability**

- EM: Q2 2020
- PFM: Q3 2020

**Performance characteristics**

- **Number of channels**: 48
- **Antenna inputs**: 1 (2 in option); supports both active and passive antenna(s)
- **Signals and frequ.**: Galileo E1b and E5a; GPS L1C/A and L5I/Q
- **Acquisition sensitivity**: (dBHz, for $P_d=0.9$) 28 (L1); 31 (E1b)
- **Tracking sensitivity (dBHz)**: 20 (L1, E5a); 22 (L5); 24 (E1b)
- **Warm / cold TTFF**: < 10 s / < 60 s
- **Typical pos. accuracy**: < 5 m (3D rms)
- **PPS signal (RS-422)**: < 50 ns rms
- **TM/TC**: UART, CAN in option (other interfaces possible). Fully compliant with PUS/CCSDS standard.
- **Update rate**: 1 - 10 Hz
- **Physical characteristics (TBC)**
  - **Power / voltage**: 8 W typical at 5 VDC
  - **Mass**: 1300 gr
  - **Dimension**: 219.5 x 110.5 x 59 mm
  - **Operating temperature**: -20°C - +50°C
  - **Lifetime**: Min. 5 years in LEO

**Proprietary global reference network supporting GPS, GLONASS, BEIDOU, & Galileo**

- **Orbit & Clock, Real time**
- **Position**: <10 cm
- **Velocity**: < 5 mm/s
- **Time**: < 5 ns

**High availability & redundancy**

- **Track record & SLA’s**

*Tested in a typical LEO orbit, all SVs at 44 dB-Hz*
NAVILEO within the spaceborne receiver ecosystem

- **Current solutions:**
  - High Reliability / High cost

- **Absolute navigation (LEO):** 10m
  - PLEIADES, DMC, Globalstar2Gm Proba-2, Demeter, EarthCare, COSMO-SKYMED

- **Absolute nav GEO/HEO:** 50-150 m
  - STENTOR, SkyLAN, InteSat, GMP, SmallGEO, STE-QUEST

- **Launchers GNS/GTO:** 15 m
  - ARIANE6, evols of ARIANEV and VEGA

- **Telecom (LEO/GEO):** 100ns
  - GEO telecom, GLocalstar2G, O3B

- **Scientific GNSS-R (LEO):** m
  - UK-DMC, CYGNSS

- **Scientific GNSS-RO (LEO):** cms/0.1mm/s
  - MetOp, CHAMP, MetOp2G, COSMIC, OCEANSAT-2, SAC-D, MEGHA-TROPIQUE

- **Scientific POD (LEO):** 0.01 m -2 m
  - GOCE, SWARM, GMES sentinels, CHAMP, GRACE, BIOMASS, DEMETER, STE-QUEST

- **Relative navigation (LEO/GEO):** cms-1 m
  - FF LEO cms / GEO 1m
  - (GRACE, PRISMA, Proba-3, MMS, TerraSAR-X/TD-X)
  - RV 1cm-10m
  - Scientific GNSS-RO (LEO): cms/0.1mm/s
    - (MetOp, CHAMP, MetOp2G, COSMIC, OCEANSAT-2, SAC-D, MEGHA-TROPIQUE)

- **Relative navigation (LEO/GEO):** cms-1m
  - FF LEO cms / GEO 1m
  - (GRACE, PRISMA, Proba-3, MMS, TerraSAR-X/TD-X)
  - RV 1cm-10m

- **Real-time POD (LEO):** 0.3 m -3 m
  - SWARM, GMES sentinels, Topex-Poseidon

- **Real-time POD:**
  - (SWARM, GMES sentinels, Topex-Poseidon)

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- **Real-time POD (LEO):** 0.3 m -3 m
  - (SWARM, GMES sentinels, Topex-Poseidon)

- **LEO OBC solutions**
  - Newspace solutions
  - Cubesats

- **- Very low performance**
  - - Lower Reliability / Lower cost

- **- High performance**
  - - Lower Reliability / Lower cost

- **Institutional market**

- **NewSpace market**

- **NAVILEO + Fugro SPACESTAR™**
Future plans for the product

**Step 1:** availability of NAVILEO's baseline version for Q2 2020 (EM) and Q3 2020 (PFM)

| NAVILEO GALE1/E5a+GPSL1/L5 | NAVILEO | High-performance GAL. E1/E5a + GPS L1/L5 space GNSS receiver for LEO spacecrafts |

**Step 2:** in parallel, additional developments of NAVILEO to target additional applications / market segments

- Real-time onboard POD algorithms
  - + Fugro Spacestar For missions requiring <10 cm 3D rms POD (real-time, absolute or relative)
- Implementation of very high sensitivity algorithms
  - NAVIMOON For more demanding missions in GTO, GEO, HEO, MTO, and to the Moon!
- Addition of GNSS signal re-generation capabilities
  - LEO-PNT For leveraging LEO mega-constellations as alternate GNSS providing secured position, navigation and time, or synchronization of payload to GNSS time

**Step 3:** NAVILEO evolution (improvements and additional capabilities)

Jan. 23, 2020
### Step 1: availability of NAVILEO’s baseline version for Q2 2020 (EM) and Q3 2020 (PFM)

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### Step 2: in parallel, additional developments of NAVILEO to target additional applications / market segments

- **Real-time on-board POD algorithms** (Fugro Spacestar) for missions requiring <10 cm 3D rms POD (real-time, absolute or relative)
- Implementation of very high sensitivity algorithms (NAVIMOON) for more demanding missions in GTO, GEO, HEO, MTO, and to the Moon!
- Addition of GNSS signal re-generation capabilities (LEO PNT) for leveraging LEO mega-constellations as alternate GNSS providing secured position, navigation and time, or synchronization of payload to GNSS time

### Step 3: NAVILEO evolution (improvements and additional capabilities)

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#### Step 1: availability of NAVILEO’s baseline version for Q2 2020 (EM) and Q3 2020 (PFM)

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#### Step 2: in parallel, additional developments of NAVILEO to target additional applications / market segments

- Real-time on-board POD algorithms + Fugro Spacestar
  - For missions requiring < 10 cm 3D rms POD (real-time, absolute or relative)

#### Application benefits:
- Fully integrated within NAVILEO (no need for additional antenna)
- No need to download GNSS raw data and post-processing via ground infrastructure
- Allows for real-time on-board data processing
- Reduced product latency

#### POD Performance:
- Position better than 10 cm 3D rms
- Velocity better than 5 mm/s
- Time better than 5 ns

Image source: Fugro
**Future plans for the product**

| Step 1: availability of NAVILEO’s baseline version for Q2 2020 (EM) and Q3 2020 (PFM) |
|----------------------------------|----------|---------------------------------------------------------------|
| NAVILEO GALE1/E5a+GPSL1/L5       | NAVILEO  | High-performance GAL. E1/E5a + GPS L1/L5 space GNSS receiver for LEO spacecrafts |

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**NAVISP E1-023 : NAVIMOON project**

- **Goal:** development of a Moon GNSS receiver prototype (EM)
- **Applications**
  - Autonomous navigation for Earth – Moon Transfer orbits
  - Autonomous navigation for cis lunar orbits
  - More...
- **Characteristics**
  - Based on NAVILEO + higher sensitivity + tightly coupled navigation filter (GNSS+OF) + ...
- **Availability**
  - EM: Q1 2021
Future plans for the product

### Step 1: availability of NAVILEO’s baseline version for Q2 2020 (EM) and Q3 2020 (PFM)

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### Step 2: in parallel, additional developments of NAVILEO to target additional applications / market segments

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<th>Target Markets</th>
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### LEO PNT demonstrator: NAVILEO receiver + POD SW + GALILEO-like signal re-generator and transmitter

- **Applications**
  - Alternate LEO PNT constellation for governmental, IoT, road transportation users

- **USP & Differentiators**
  - POD solution + signal regeneration time/frequency synchronized with GNSS time ↔ interoperability & compatibility
  - High dynamics ↔ Fast PPP convergence
  - Alternate PNT ↔ more security
  - Stronger signals ↔ IoT

- **Availability**
  - Demonstrator: Q2 2020
NAVISP El. 2 benefits

- Very flexible and effective programmatic Element 2 framework:
  - ESA/SME co-funded scheme
  - Enables company to propose a project and define the product specifications, ...
  - Ownership of developed IP remains to Industry
  - Fast submission & feedback process

- Great ESA support:
  - Project follow-up and constructive feedback/guidance through regular progress meetings & milestones
  - Access to some of ESA facilities / experts
  - Proposed a full evaluation of our final product (EM) at the end of the project

Enabled the creation of a new GNSS product line in Syderal!
from LEO → to LEO PNT → to MOON applications!
Acknowledgments:

• Swiss ESA delegation (Swiss Space Office)
• NAVISP P.O. (A. Fiumara and P. Manchini)
• Our ESA Project Officer (Pietro Giordano)
• My colleagues in Syderal