AGGA-4 Final Presentation

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Acknowledgment

- Industrial partners:
  - Airbus GmbH: Designer of the AGGA-4 ASIC
  - RUAG-Austria: Requirements & FPGA validation
  - ATMEL: Layout, manufacturing and testing

- ESA team, in particular:
  - MicroElectronics section in D/TEC: R. Weigand
  - Navigation Section in D/TEC: G. López Risueño, J.Perelló
  - Technical Officers: P. Silvestrin, J.Roselló (D/EOP Future Missions Div.)
  - Funding sources

Contractual facts

Contract 16831/03/NL/FF

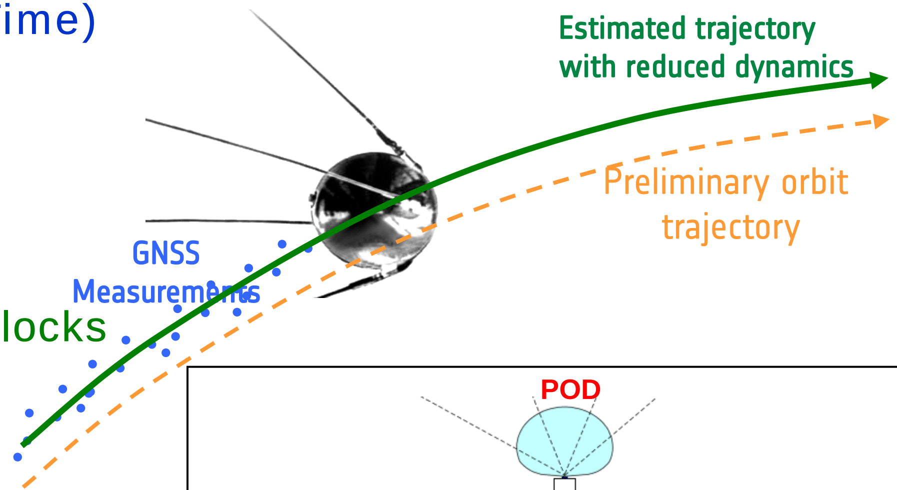
- 2003: AGGA-3 Requirements (upgrade of AGGA-2) up to initial layout
- 2008: AGGA-4 (Rider1 +6 CCNs) to upgrade (AGGA3) design + manufacturing
- 2014: delivery in June of 20 engineering prototypes
  - (Final Report in Dec-2014)

- Co-funded through several programmes:
  - EOPA (EO Prep.Activ): 56%
  - TRP : 13%
  - GSTP : 10%
  - MetOp-SG : 21%

Applications

- On-Board Navigation (Position, Velocity, Time)
  - Continuous availability

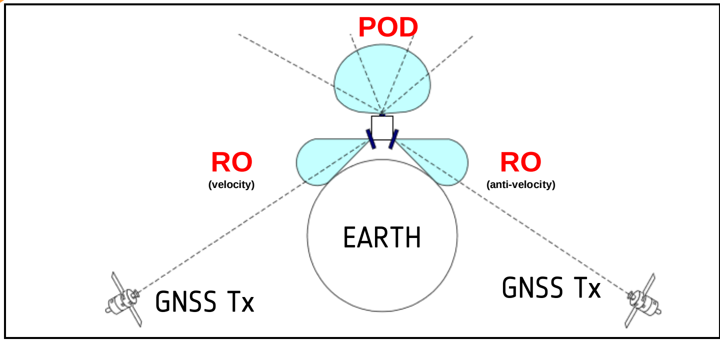
- Precise Orbit Determination (POD)
  - Post-processing to correct GNSS Tx clocks
  - 2cm level proven (GOCE)

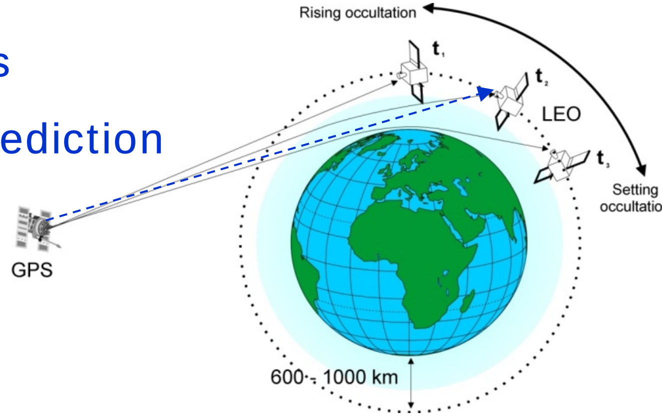


- Scientific Instruments: Radio Occultation
  - Carrier phase measurements (like POD)
  - Refractivity causes Bending Angle

    => Temperature, Pressure, Humidity profiles

  - Among top 4 measurements for Num.Weather Prediction

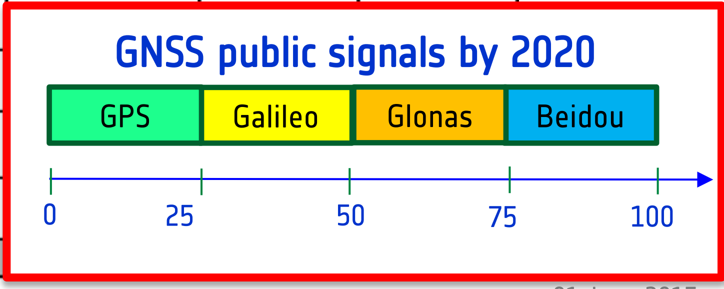




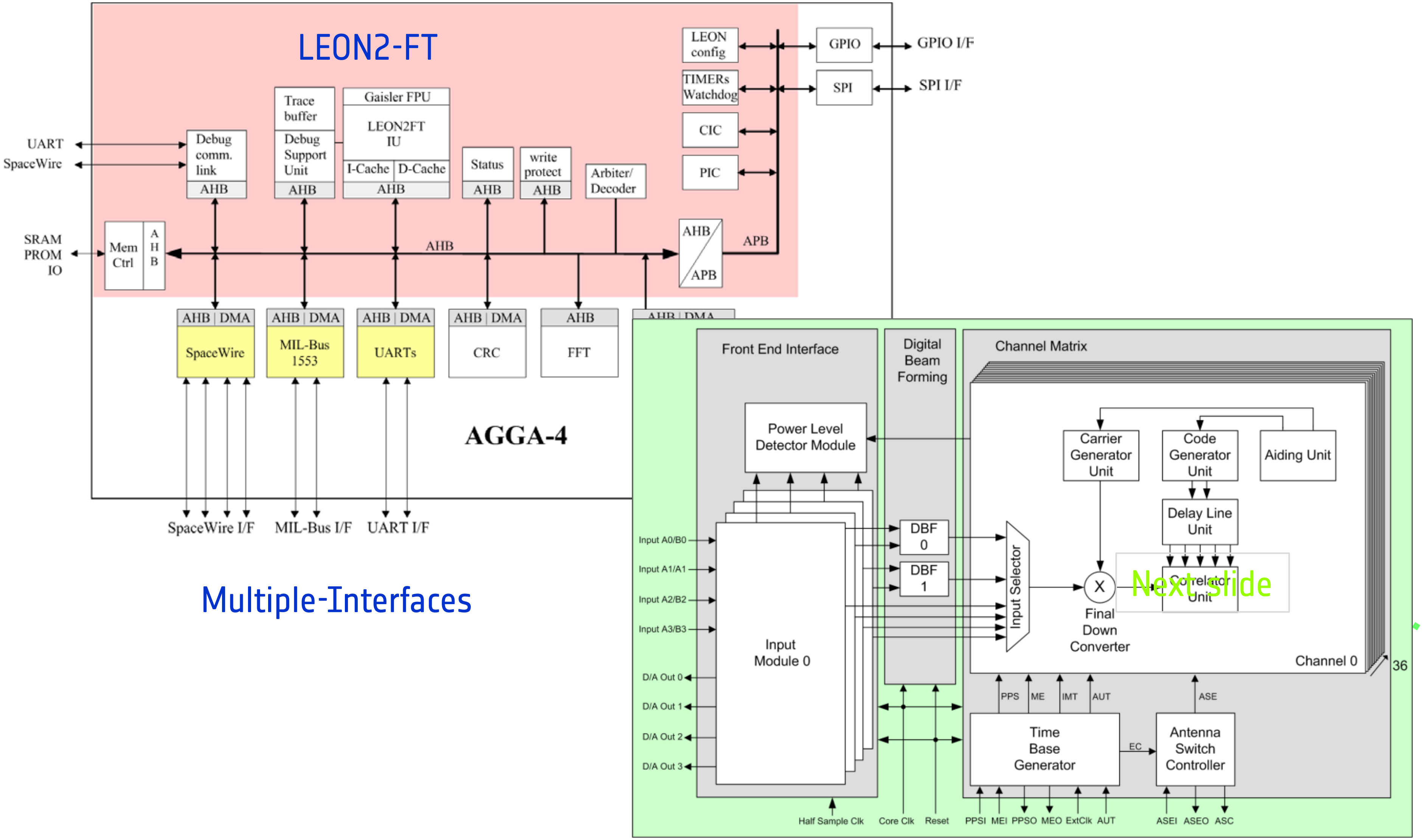
AGGA-4: compatible signals

- relying on **public** (not encrypted) signals & compatible with GLONASS and Beidou (e.g. BOC(2,2), BOC(4,4) as known today)
- two component (pilot/data) signals in one channel (thanks to double code generator)

Constellation	Band	Freq. fo (MHz)	Component	Primary Code Rate (Mcps)	Primary code length (chips)	Secondary code length (chips)	Symbol/ Data Rate sps / (bps)	Modulation in AGGA-4	LFSR/ Memory (config. AGGA4)	AGGA4 nb. Channels
Galileo	E1	1575.42	E1 B	1.023	4,092	No	250/125	BOC(1,1)	Memory	1 SF
			E1 C	1.023	4,092	25	Pilot	BOC(1,1)	Memory	
	AltBoc	1191.79	E5a + E5b							
	E5a (E5b)	1176.45 (1207.14)	E5a-I (E5b-I)	10.23 (idem)	10,230 (idem)	20 (4)	50/25 (Pilot)	BPSK(10) (idem)	LFSR (idem)	1 SF (idem)
			E5a-Q (E5b-Q)	10.23 (idem)	10,230 (idem)	100 (idem)	(250/125) (Pilot)	BPSK(10) (idem)	Memory (idem)	1 SF (idem)
Modernized GPS	L1c	1575.42	L1Cd	1.023	10,230	No	100/50	BOC(1,1)	Memory	1 SF
			L1Cp	1.023	10,230	1800	Pilot	BOC(1,1)	Memory	1 SF
	L1	1575.42	L1 C/A	1.023	1,023	No	50	BPSK(1)	LFSR	1 SF
	L2C	L2C	L2CM	10.23	10,230	No	50/25	BPSK(0.5)	Memory	1 SF
			L2CL	10.23	767,250	No	Pilot	BPSK(0.5)	LFSR	
	L5	1176.45	L5-I	10.23	10,230	10	100/50	BPSK(10)	LFSR	1 SF
Glonass	L1OC	1575.42	L1OCd (L1OCp)	10.23 (idem)	10,230 (idem)	(-) 1800	100 (Pilot)			
	L5OC	1176.45	L5OCd (L5OCp)	10.23 (idem)	10,230 (idem)	10 (20)	100/50 (Pilot)			
Compas-Beidou	B1a	1575.42	B1ad (B1ap)	1.023 (idem)	4,092 (idem)	- (25)	250/125 (Pilot)			
	B2a	1175.42	E5a-I (E5b-I)	10.23 (idem)	10,230 (idem)	20 (100)	50/25 (Pilot)			
	B2b	1191.79	AltBoc							



AGGA-4 architecture



Feature	AGGA-4	AGGA-2
FRONT END I/F	4 Input Modules supporting: IFC, R2C, and DDC (Digital Down Conversion from IF) 3 bit => 0.17 dB implementation loss Enhanced Power Level Control (PLC)	4 Input Modules supporting: IFC (for I/Q), and R2C (real sampling) 2 bit => 0.55 dB imp. loss One PLC per Input Module
Digital Beam Forming	2 DBF combining inputs from 2 antennas: Inputs from 4 antennas	2 DBF – by digital phase shifting (same as in AGGA-4)
GNSS CHANNELS	(main changes in bold letters)	
# of channels	36 Single Freq. or 18 DF (target)	12 SF or 4 DF
Compatible signals	Galileo Open Serv.: E1bc, E5a, E5b Modernized GPS: L1 C/A, L1C, L2C, L5 Existing FDMA Glonass Beidou, modernized Glonass (CDMA), (as known today)	GPS L1 C/A Semi-Codeless L1/L2 Existing FDMA Glonass
Code Generators	(2 code gener. per channel for Pilot and Data) Primary: Flexible LFSR and memory based Secondary codes and BOC(m,n) subcarriers -> for Galileo	1 code generator per channel Fixed LFSR for certain primary codes No secondary code and no BOC.
Delay Line	Dual stage for pilot and data	Single stage
Correlators per channel	5 complex (I/Q) with EE, E, P, L, LL and autonomous NAV data bit collection	3 complex (I/Q), with E, P, L, where E=early, P=Punctual, L=Late) NAV data bit collection requires software interaction
Codeless P(Y)	No	Yes (4 P-code units) – ESA patent
Channel Slaving	Hardware and software slaving	Hardware slaving
Aiding Unit per channel	Yes: Code and Carrier aiding	No. Done in software
Observables	16 Integration Epoch (IE) Observables (DMA capable) 5 Measurement Epochs (ME) Observables (DMA capable)	6 IE Observables (no DMA) 2 ME Observables (no DMA)
Common to all channels	Antenna Switch Controller (ASC) Time Base Generator (TBG) with ME, PPS, IMT counter, External Clock interface extended reset detection section	ASC TBG with ME and PPS
MICRO-PROCESSOR	LEON-2 FT on-chip with IEEE-754 compliant GRFPU (Float.Point)	Off-chip (typically ERC-32, ADSP 21020)
CRC MODULE	On-chip	No – task done in software
FFT MODULE	On-chip (128 points , fixed format) - (ideal for fast acquisition,)	No – task done in software
EXTERNAL INTERFACES	Four SpaceWire SE , Two DMA capable UART, Mil-Std-1553, SPI I/F, DSU, S-GPO, 32 GPIO, SRAM I/F	Microprocessor I/F, Interrupt controller and I/O ports
TECHNOLOGY	**ATMEL ATC18RHA 0.18 mm, 352 pins ;** 6 Mgates ; **GNSS clock up to 50 MHz** **Die size: 13x13mm incl. pads** **LEON clock up to 87 MHz**	0.5 micron from ATMEL, 160 pins ; 200 k gates (die size 10x10 mm including pads) GNSS clock up to 30 MHz

AGGA-4: enabler for many more R&D activities

GNSS Receiver Activities initiated since 2012 (when pin out was known):

- GAMIR Dual Freq. receivers up to EQM level: (one Airbus, one RUAG-A)
- Single Freq. Rx: one Airbus (EM), one RUAG-A (concept + SW simulations)
- OBC with AGGA-4 GNSS (for Telecom. sat): with TAS-I

Validation activities:

- FPGA level (done): (RUAG-A, part of C16831+Prodex) + Deimos Portugal
- ASIC level: (RUAG-A) to check performance + characterisation in temperature

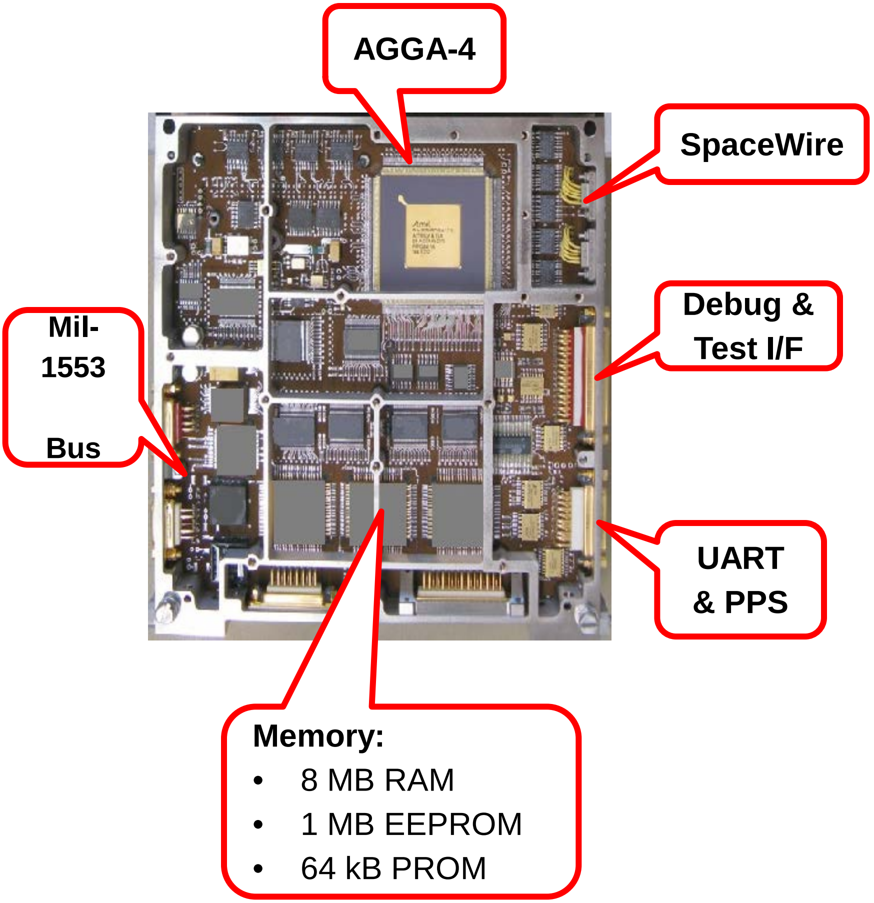
Simulators with Deimos Port: for SW development without having the AGGA4 chip

AGGA-4 eval. Commercial kit (under preparation)

AGGA-4 SEU Radiation characterisation (under preparation)

Developments for missions : MetOp-SG (best practices), Proba-3

AGGA4 applicationsGAMIR Astrium



Airbus GAMIR board

<u>AGGA4 key points</u> :

- Galileo compatibility
- radio-occult. & replace AGGA2 + DSP 21020 used on METOP (GRASS instrument)
- High channel Nb. (36): suitable for multi-GNSS

<u>Missions</u>:

- CSO (CNES): French military optical recognition
- MetOp-SG (MOS): 4 AGGA4 per sat. x 6 sat.
  → 24 parts (first launch 2021)
- PROBA-3: 2 satellites (launch end 2018)

- Candidate (driver is Galileo compatibility) for:
  - o Sentinels 1C, 1D, 2C, 2D , 3C, 3D
  - o all future LEO missions
  - o GEO / GTO app. : good prospects
    - No ground tracking during slow orbit raising by electrical propulsion → GNSS opportunity
    - weak signals, weak geometry using GNSS Tx side-lobes→ overcome with multi- GNSS

Conclusion

Applications: Precise Orbit Determination (POD) and Radio Occultation

AGGA-2 baseband processors: widely used since 200

– ESA: e.g. MetOp-GRAS a/b/c for RO, GOCE, Sentinels 1/2/3, Swarm, EarthCARE, etc.

– Non-ESA: e.g. ROSA in Oceansat-2 & MeghaTropiques, SAC-C &D, Radarsat-2, Cosmo-Skymed,

AGGA-4 : Final presentation today by Airbus

- already widely used (R&D , also in developments for missions)