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AGGA-3

Next Generation GNSS ASIC

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Agenda

- Background (short resume of AGGA so far)
- Motivation of AGGA-3 Development
- Status AGGA-3 Development
- Key AGGA-3 Features
- AGGA-3 Application Review
- Summary

Background

- AGGA (Advanced GPS/GLONASS ASIC) development initiated within the Earth Observation Preparatory Programme (EOPP) to support Earth observation (EO) applications of navigation signals
- Radiation-tolerant digital integrated circuit providing all the high-speed digital signal processing functionality for ‘precise’ GNSS applications
- EO applications:
  - radio occultation (RO);
  - precise orbit determination of low-Earth orbiters for gravity field determination, altimetry, radar interferometry, etc. ;
  - scatterometry and altimetry with GNSS reflected signals
- AGGA chip developed through co-operation with several European space industries and ESA internal activities
- Current version: AGGA-2a available to industry as an application-specific standard product (T7905E component from ATMEL)

Recall of Key AGGA-2 Features (1)

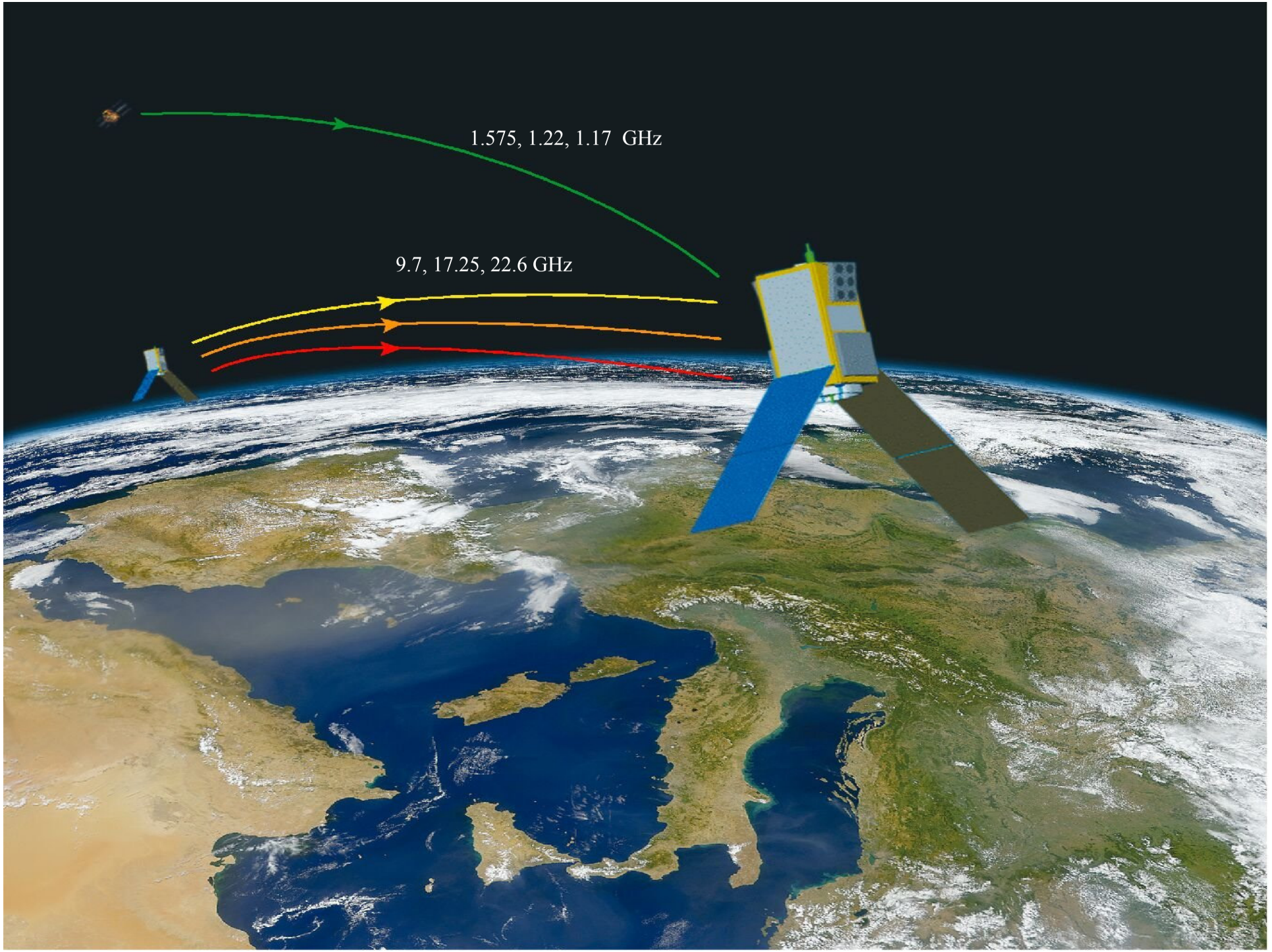
- 12 single frequency channels (36 complex correlators), each capable of tracking any GNSS C/A code signals
- 4 P-Code Units for dual-frequency operation and semi-codeless tracking (ESA-ISN patent)
- Supported: IF sampling ($f_s/4$), real-to-complex conversion, final down-conversion,
- highly configurable and programmable, e.g.
  - pairs of single frequency channels configurable for attitude determination (hybrid parallel-multiplex architecture, ESA-ISN patent)
  - slaving of three single frequency channels together with P-Code Unit into one dual frequency channel capable of tracking GNSS C/A Code on L1 and P-Code on L1 and L2 (using semi-codeless tracking)
  - slaving of up to nine channels for fast acquisition
  - slaving for multi-path mitigation (also supports time-multiplexed multipath mitigation)

Recall of Key AGGA-2 Features (2)

- Narrow correlation supported
- Either eight real inputs or four complex inputs, each 2 bit wide; different input formats supported
- Signal level detector, clock and time-base generator; antenna switch controller
- 32-bit microprocessor interface (compatible with TSC21020 and ERC32) with interrupt controller and basic IO port
- System support: parallel I/O (monitoring & redundancy), Clk output, reset handling
- Max CoreClk: 30 MHz (ClkIn: 60 MHz)
- Technology: 200 kgates in ATMEL MG2-RT sea-of-gates using MG2-265 matrix
- 160-pin MQFPL package with 25 mil pitch

AGGA-based Equipment

- Saab Ericsson Space / Austrian Aerospace
  - GRAS (GNSS Receiver for Atmospheric Sounding) on METOP (1, 2 and 3)
  - GPSOS (GPS Occultation Sensor) on NPOESS (US 'converged' meteo satellites)
- LABEN
  - EGNOS RIMS-B Reference Receivers (many)
  - LAGRANGE experiment (with AGGA-0!) on SAC-C
  - LAGRANGE (Precise Orbit Determination) for Radarsat-2
  - ROSA RO instrument for ASI missions
  - SSTI (Precise Orbit Determination) for GOCE
- EADS ASTRIUM
  - MOSAIC GNSS Receiver
- Septentrio
  - commercial products based on AGGA-0-derivative (GReCo 1A01)


1.575, 1.22, 1.17 GHz
9.7, 17.25, 22.6 GHz

Motivation of AGGA-3 Development

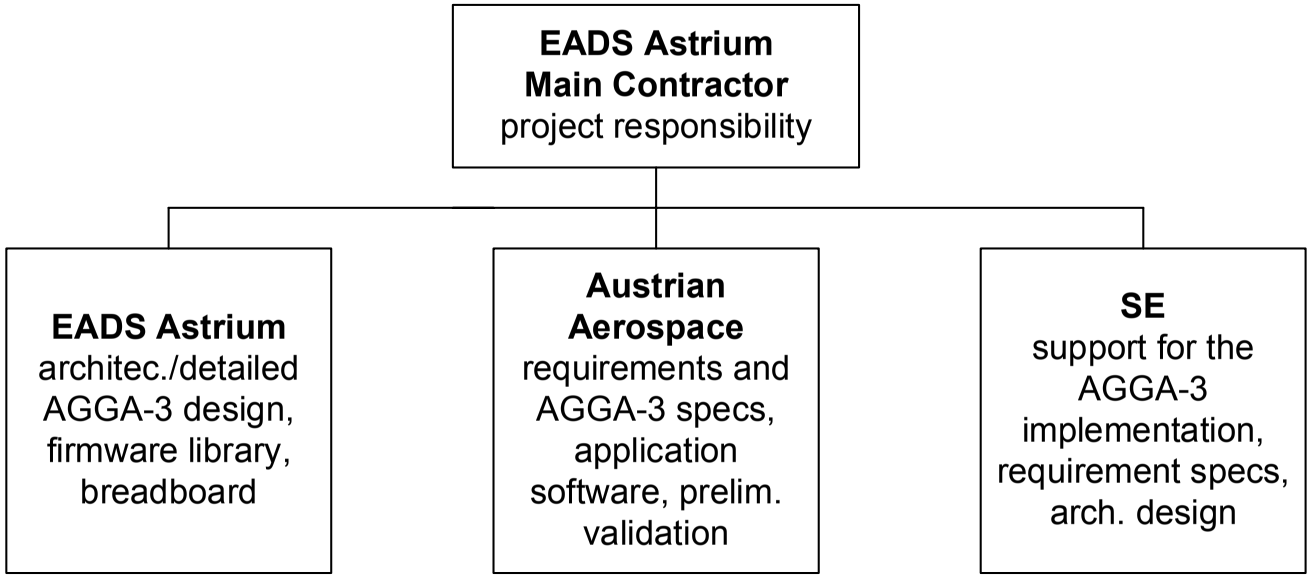
- Get AGGA up-to-date with applications, signal processing techniques and technologies, e.g.:
  - understanding of processing optimal for atmospheric sounding improved from experience with GRAS and Lagrange
  - need for more compact, low-consumption RO and POD instruments for various planned ESA EO missions (ACE+, SWARM,OEW,..)
  - signals of navigation satellites being enhanced (e.g., use of pilot signals for RO)
  - Galileo development (additional measurements of enhanced quality)
  - improved (GNSS) signal processing techniques
  - IP of powerful processor cores (LEON SPARC) available for space applications
  - vastly improved space ASIC technology (0.18 um)
  - AGGA User Meeting held for feedback and critical comments on AGGA-3 requirements
- next generation of AGGA also as a standard product
- development of firmware
- samples, datasheet, support know-how over 3 years
- validation of navigation functionality
- ESA missions needing AGGA3-based instruments under preparation
- validation w.r.t. RO applications planned (separate contract)

Objectives for AGGA-3

- Allow for miniaturised receiver
  - high integration, minimise power consumption
- Support as many applications as possible
  - flexible interfaces
  - modernised GPS, Galileo
- Fulfil signal processing tasks and performance requirements
  - solid basis from AGGA-2
  - increase of resolution
- High degree of usability
  - support for embedded SW (reduction of processor load, decoupling of SW-tasks)

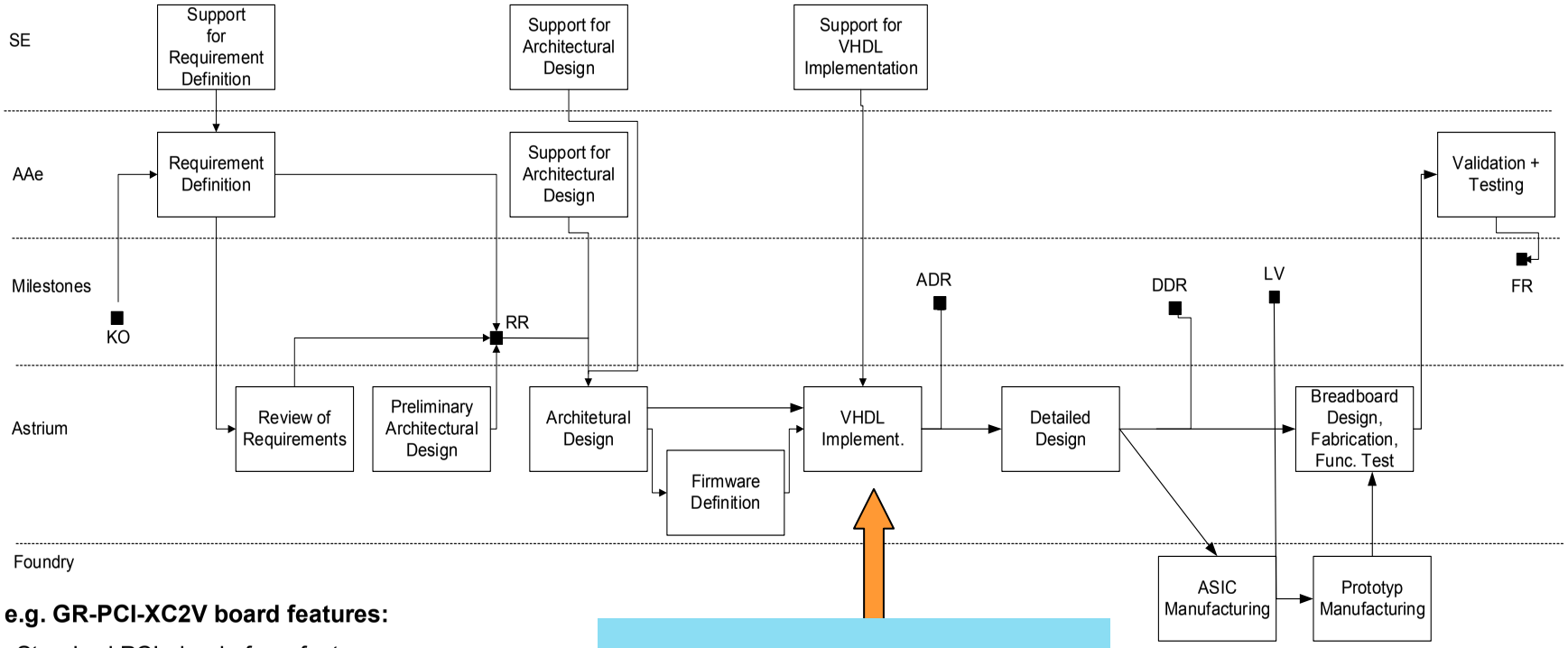
Status AGGA-3 Development

- EADS Astrium prime with AAe as subco, SE support functions



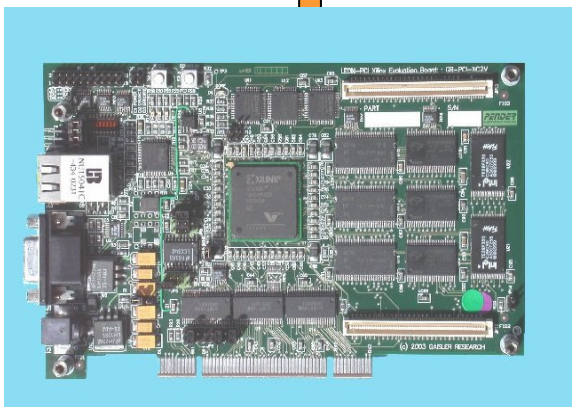
- Baseline ATC18RHA technology from ATMEL
- Consultation of AGGA Users in April 2003 to refine requirements
- Architectural design on-going. ADR planned for mid September 2004.
- Planned for MPW run in second quarter 2005

AGGA-3 Study Logic



e.g. GR-PCI-XC2V board features:

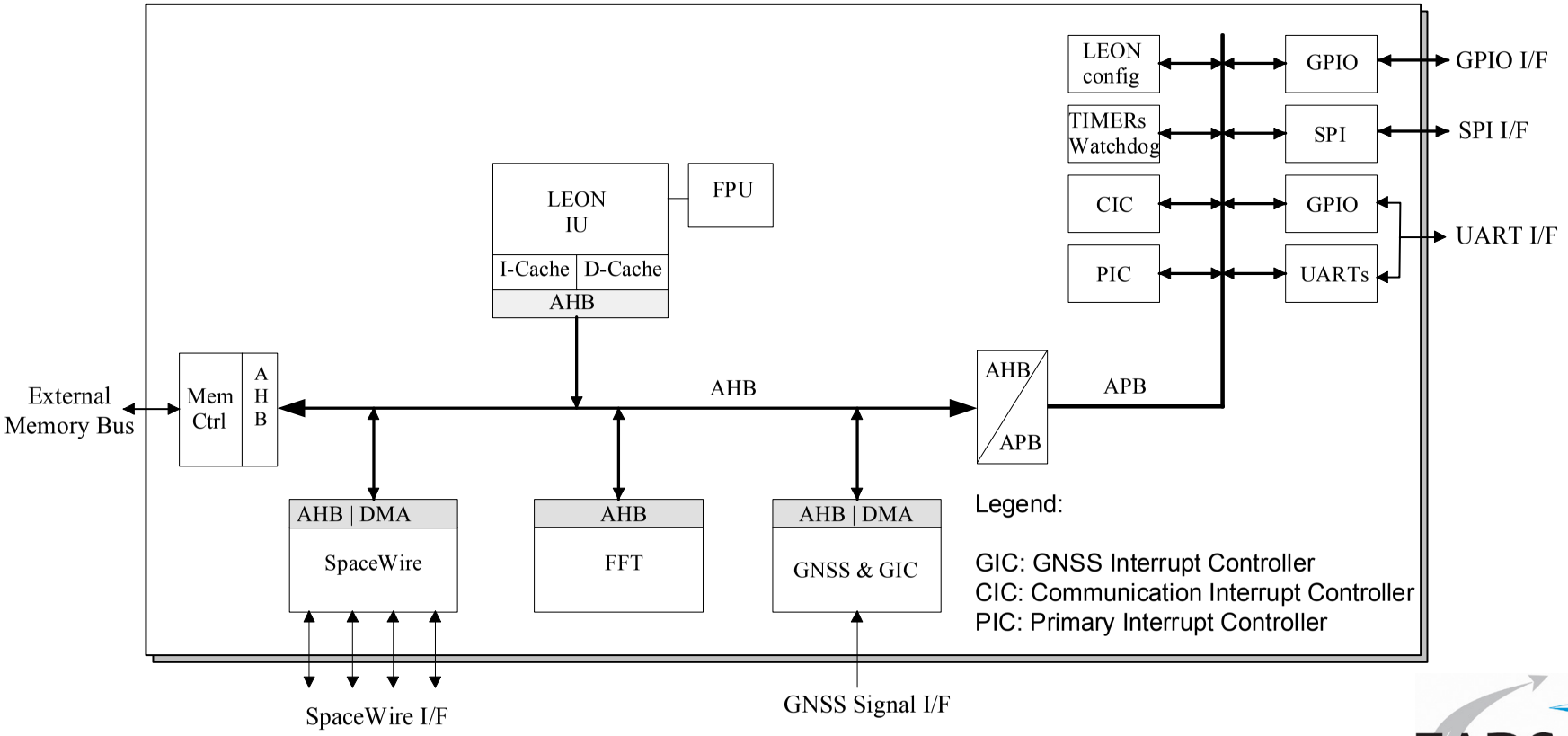
- Standard PCI plug-in form factor
- Virtex-II XC2V3000-FG676-4 FPGA
- On-board FPGA configuration proms (3 x XC18V04)
- 8 Mbyte flash prom (2M x 32)
- 1 Mbyte static ram (256K x 32)
- 16 Mbyte PC133 SDRAM (4M x 32)
- Ethernet PHY 10/100 Mbit transeiver
- 33 MHz, 32-bit PCI interface (3V and 5V tolerant)
- Standard RS-232 UART port for DSU



- 120-pins memory and custom I/O expansion connectors (AMP-177-984-5)
- JTAG and slave-serial FPGA programming capability
- Supports LEON core frequencies up to 50 MHz
- LEON-FT memory option (40-bits wide static ram and SDRAM)

Key AGGA-3 Features (1)

- Objective: include and extend functional and performance requirements covered by AGGA-2a, except GLONASS functionality
- AGGA-3 block diagram:



Key AGGA-3 Features (2)

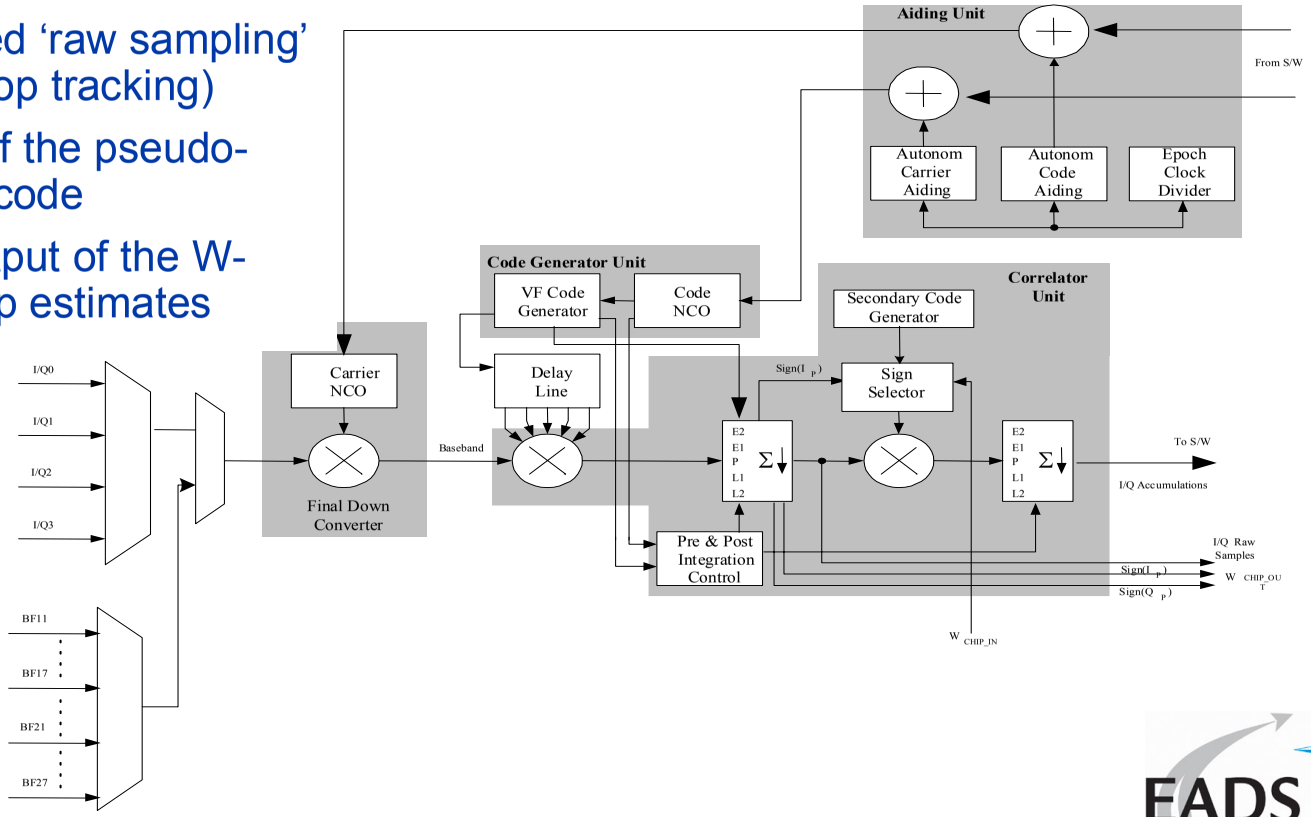
- Features On-Chip Processor Modules:
  - LEON-FT processor (clock >= 80 MHz) on single die with GNSS signal processing
  - IEEE-754 compliant FPU (GRFPU) with > 100 MFLOPS
  - interrupt controller (interrupts from dedicated inputs and other processor support functions)
  - processor watchdog
  - timer (periodic or single-shot time-outs)
  - DMA controller (dump data between GNSS signal processing core and LEON memory)
  - boot support
  - support synchronisation of different AGGA-3
  - FFT processing module for fast GNSS signal acquisition
  - fixes of AGGA-2a bugs or weaknesses (incl. improvement of initialisation, time-tagging)
  - SpaceWire links
  - UART
  - JTAG

Key AGGA-3 Features (3)

- Features GNSS module (front-end and beamforming module):
  - Support of different input formats as in AGGA-2a
  - 4 real and complex baseband inputs
  - Processing of high IF for large bandwidth signals: digital down-conversion on-chip
    - 4 antenna inputs
    - sampling rates up to 200 MHz and de-interleaving
    - down-conversion to near baseband and filtering
    - configurable re-quantisation thresholds for digital gain setting
  - 8-bit or 3-bit pre-correlation word-length
  - Enhanced power level measurement on all inputs (narrow or wideband)
  - Flexible switching of inputs to all channels
  - Digital beam-forming to form 7 fixed beams (one beam at any time per channel)

Key AGGA-3 Features (4)

- Features GNSS module (channel matrix):
  - Processing of current and 'modernised' GPS signals
  - Processing of Galileo L1G, E5a and E5b signals
  - 36 highly configurable single-frequency channels, each channel including 5 complex correlators
  - Optimised 'raw sampling' (open-loop tracking)
  - Output of the pseudo-random code
  - Input/output of the W-code chip estimates



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Key AGGA-3 Features (5)

- Features GNSS module (channel matrix):
  - Correlation is split into pre- and post-correlation
  - 10 complex correlators per single frequency channel
  - Direct memory access (DMA) of pre-correlation results
  - Time tagging of pre- and post correlation results
  - Sign estimation allows for data stripping
  - Loop aiding support
  - Channel slaving (as in AGGA-2)

Key AGGA-3 Features (6)

- Improved and additional building blocks wrt to AGGA-2:
  - Additional digital down-conversion module
  - Additional beam forming module
  - Increase of internal processing word length to 3-bit
  - Parallel accumulation of power levels and support of narrow band power level detection
  - Increase in number of GNSS channels to 36
  - Additional secondary code strip
  - Optimised raw sampling
  - Code and carrier aiding unit
  - FFT module for fast acquisition (possibility of slaving GNSS channels for a correlator bank remains)

Earth Observation Application Review

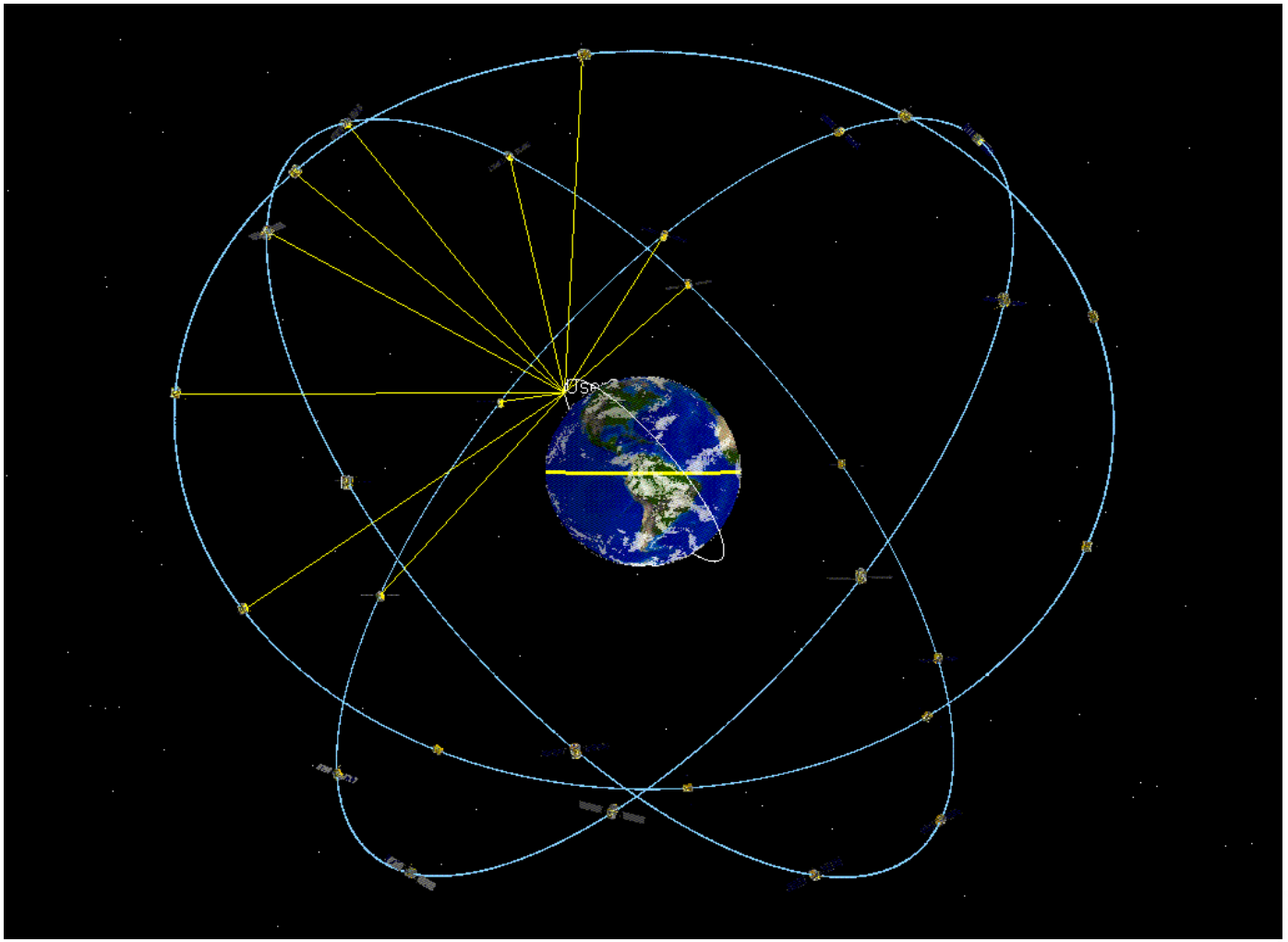
- GPS Receiver Functionalities:
  - GPS signals as sources of opportunity (e.g. for Earth observation purposes)
  - Navigation
  - Determination of S/C trajectories
  - Measure of relative distances between space vehicles
  - Delivery of precise time synchronisation to S/C electronics
  - Attitude determination
- Potential Advantages:
  - Limitation of the number of sensors & costs
  - Increase of S/C autonomy
- Applications:
  - Radio Occultation
  - Scatterometry
  - Altimetry

Navigation Application Review (1)

- Requirements on the AGGA Device
  - Autonomous operation requires high amount of processing tasks to be accomplished
    ⇒ Powerful processor, means to reduce processor load
  - High signal dynamic applications
    ⇒ support for loop aiding and fast acquisition
  - Dual-frequency operation for POD
  - FFT and high number of correlators allow for very short cold start times
  - Low cost
  - Low power consumption

Navigation Application Review (2)

- Potential Autonomous Applications:



LEO, MEO Missions and Constellations, Rendezvous operations

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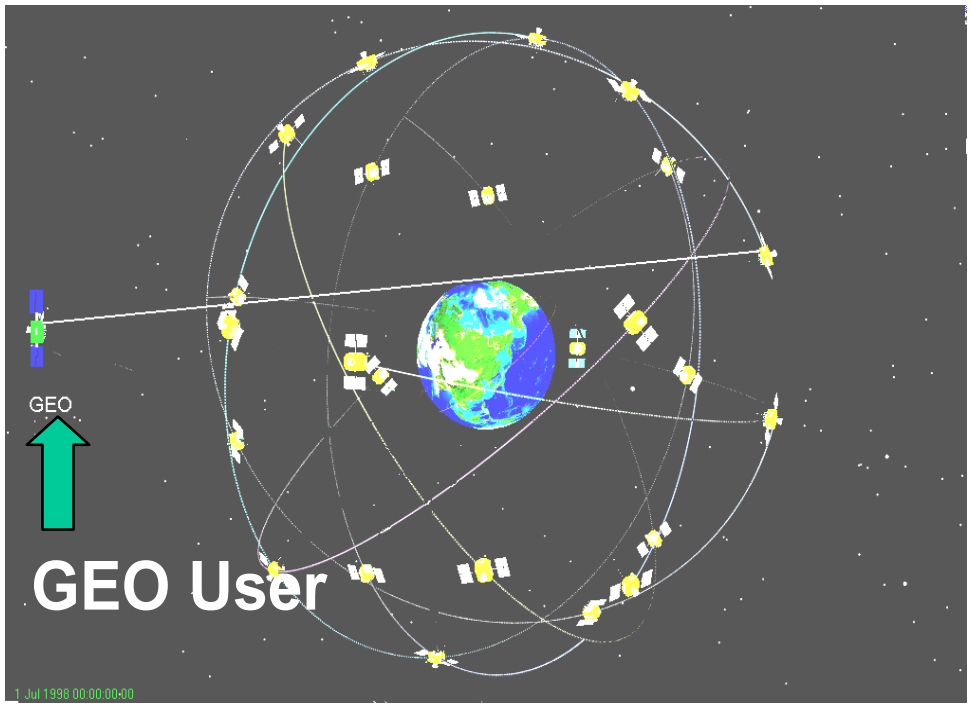
Navigation Application Review (3)

- Potential Autonomous Applications:



Autonomous Orbit Determination in GEO

Launcher, Re-Entry

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Attitude Determination Application Review

- Requirements on the AGGA device
  - Support for Hybrid Parallel-Multiplex attitude determination scheme
  - 2 dual-frequency antenna inputs
  - Low cost
  - Low power consumption
  - Versatile interface for communication with other sensors
- Potential Uses in AOCS
  - Initial Attitude Acquisition
  - Intermediate Acquisition Phases
  - Operational Phases
  - Safe mode
- Potential Configurations
  - ADGPS as 3-axis absolute attitude sensor
  - ADGPS as angular rate sensor
  - ADGPS associated with star tracker
  - GPS-based AD associated with gyroscopes

Summary

- AGGA-2 was one of the most successful standard ASIC's developed by ESA, with a range of users and applications wider than anticipated
- AGGA-3 provides enhanced high speed digital signal processing functionality, a powerful on-board microprocessor and versatile interfaces for a wide range of GNSS applications
- The powerful features and flexibility of AGGA-3 will allow GNSS space equipment developer to focus on application algorithms and software
- AGGA-3 will take advantage of a number of other European technical developments (LEON, SpaceWire,..) as well as of on-going programmes (Earth observation RO missions, Galileo,..)

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EOP - AGGA-3