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Fraunhofer Institute for Integrated Circuits IIS

5th SEFUW: SpacE FPGA User Workshop, 16 March 2023, Noordwijk

Continuous Integration in Space: An Approach to Automated Qualification of In-Orbit Experiments

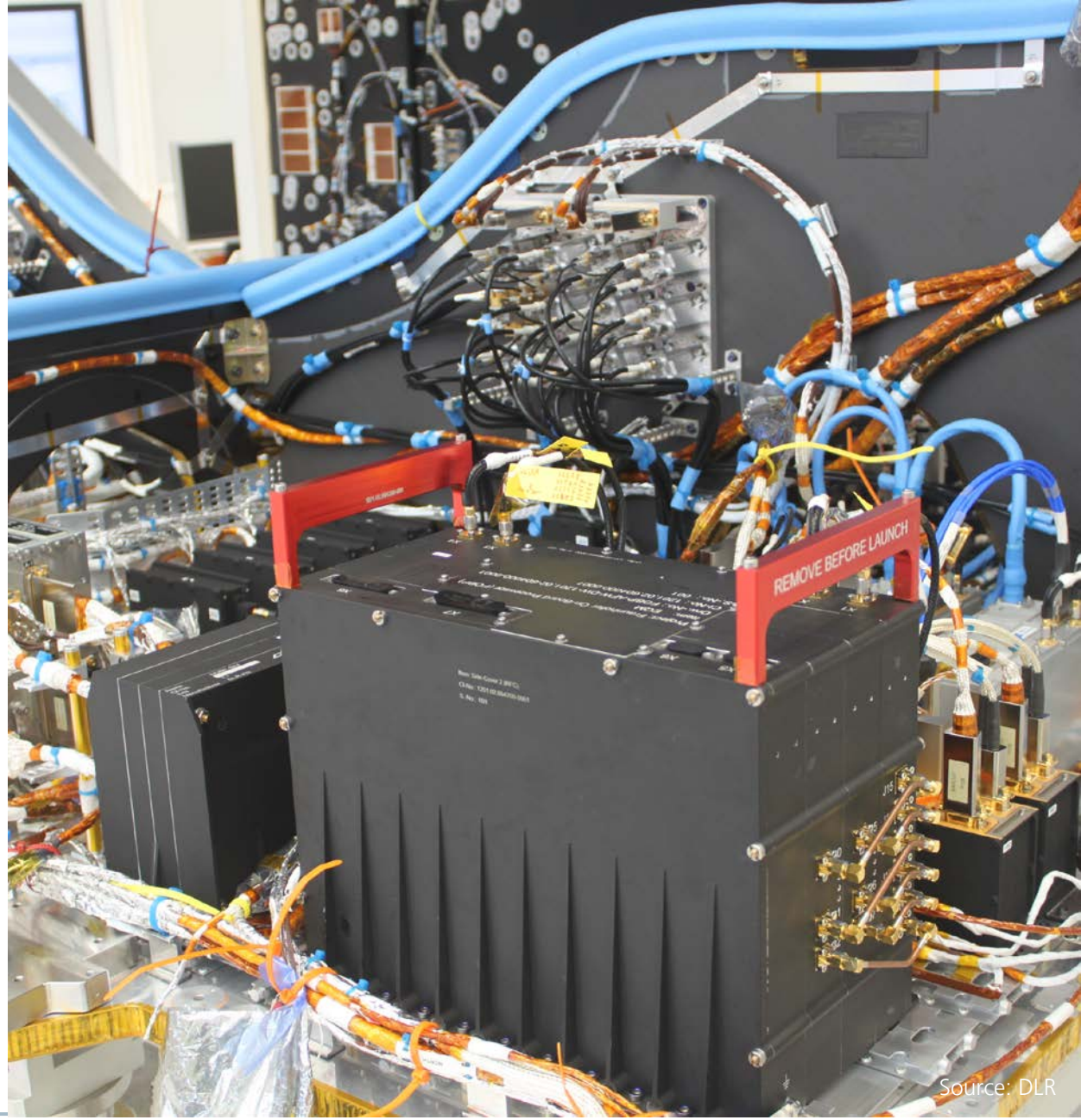
Moritz Schreiber, Katja Vornberger

Fraunhofer On-Board Processor (FOBP)

Main Features

FOBP as an example for a modern OBP

- Main use cases of the FOBP
  - In-Orbit Verification (IOV) of a FPGA-based OBP in GEO
  - Design evaluation and prototyping
  - Communication experiments
- 450 MHz bandwidth in Ka band
- In-band telemetry and telecommand link
- Two radiation-hard Virtex 5-QV FPGAs
- Reconfiguration after launch: scalable, adaptive, flexible



Source: DLR

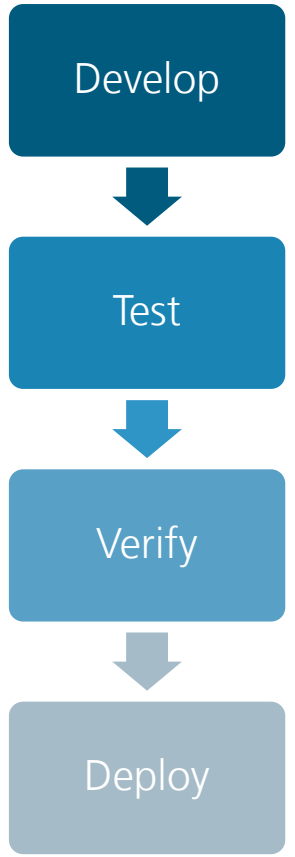
Traditional Workflow

FOBP

Time-consuming process to verify a new design

- Multiple parts with their different build-flows
- Qualifying every design targeting an experiment in space
- Securing payload configuration

Can’t this be automated?



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Continuous Integration in Space

Content

- Motivation: Fraunhofer On-Board Processor
- Continuous Integration / Continuous Delivery
- FPGA Design, Software Build and Integration
- Automated Tests
- Deployment in Space
- Next Steps and Applications

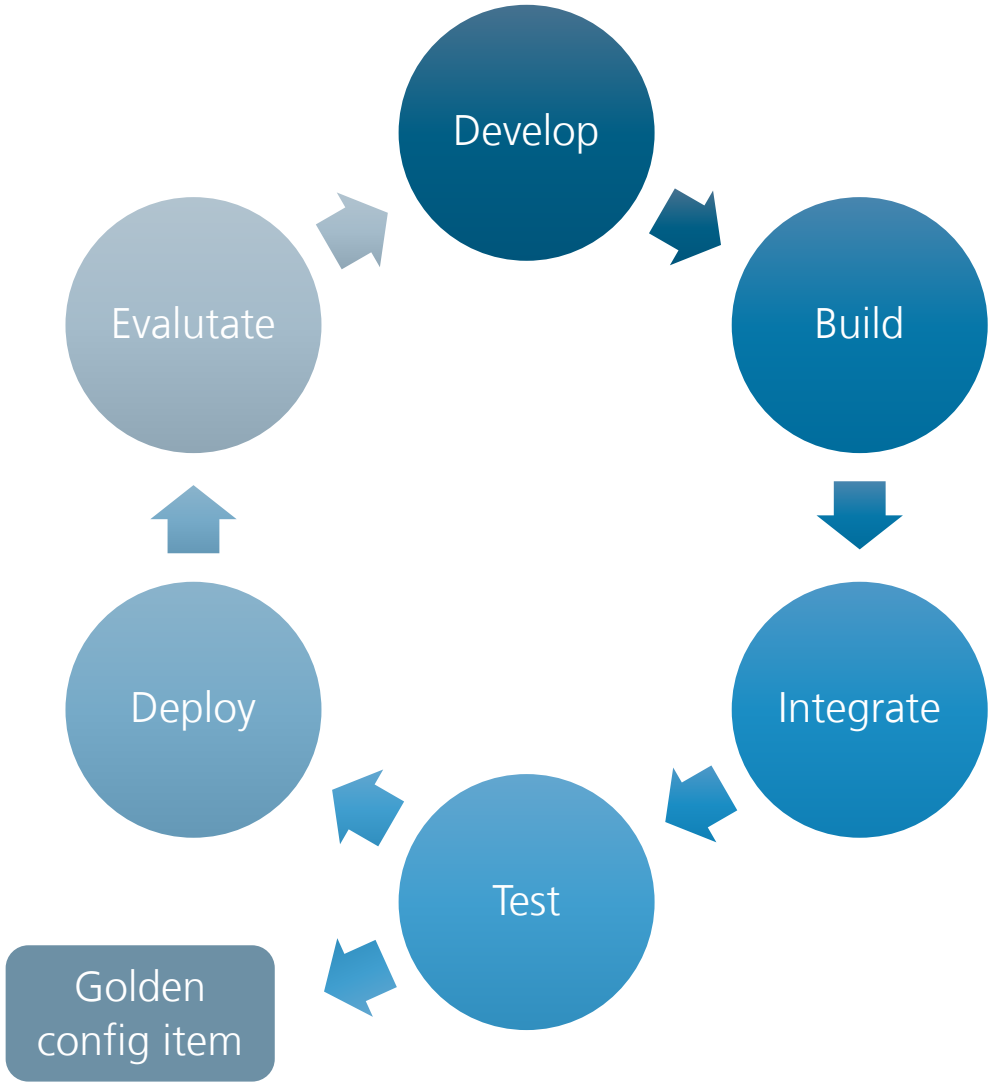
Continuous Integration / Continuous Delivery (CI/CD)

Basics

- Origin in software development
- Automation in building, testing and deployment
- Qualifying FPGA designs for space experiments on the FOBP

Advantages of CI/CD

- Minimizing human errors by incorporating advanced review process
- Reducing setup time for measurements and experiments
- Ensuring reproducibility of results



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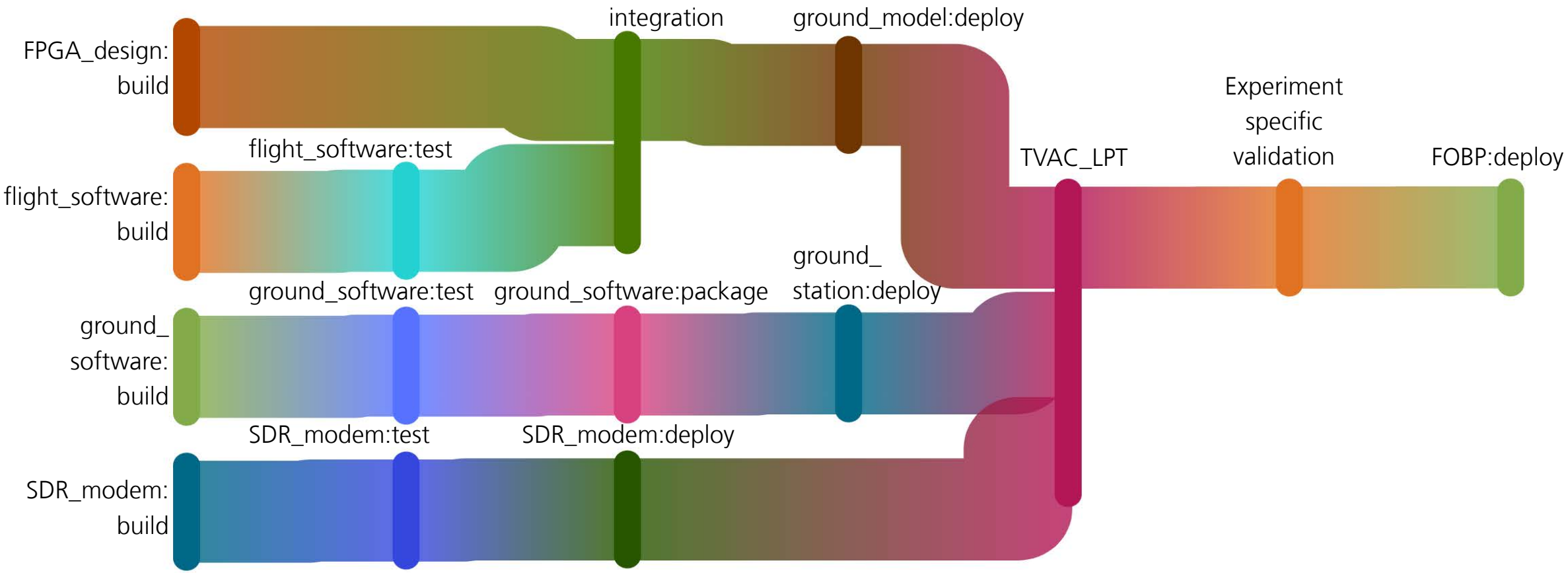
FOBP Pipeline

CI/CD in Space



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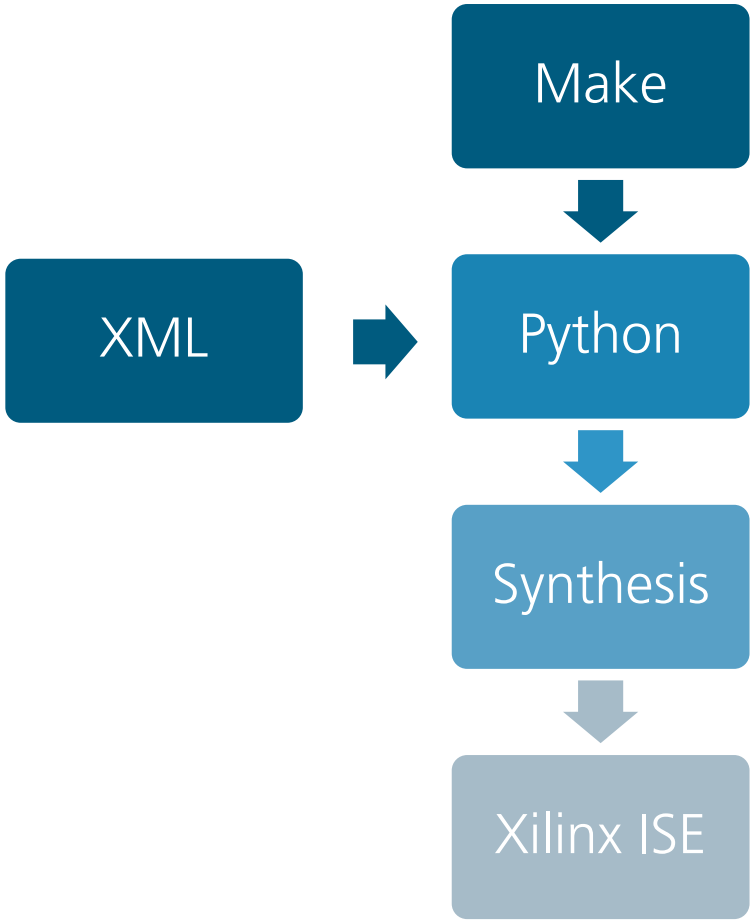
FPGA Design
CI/CD in Space

Fraunhofer IIS build flow

- Wrapper on Xilinx ISE
- Customize settings using configuration file
  - Synthesis tool Synplify or XST
  - Parameters for VHDL design
  - Parameters for Xilinx tools
- Fully automated and parallelised for multiple designs



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Software Build and Integration

CI/CD in Space

Ground segment

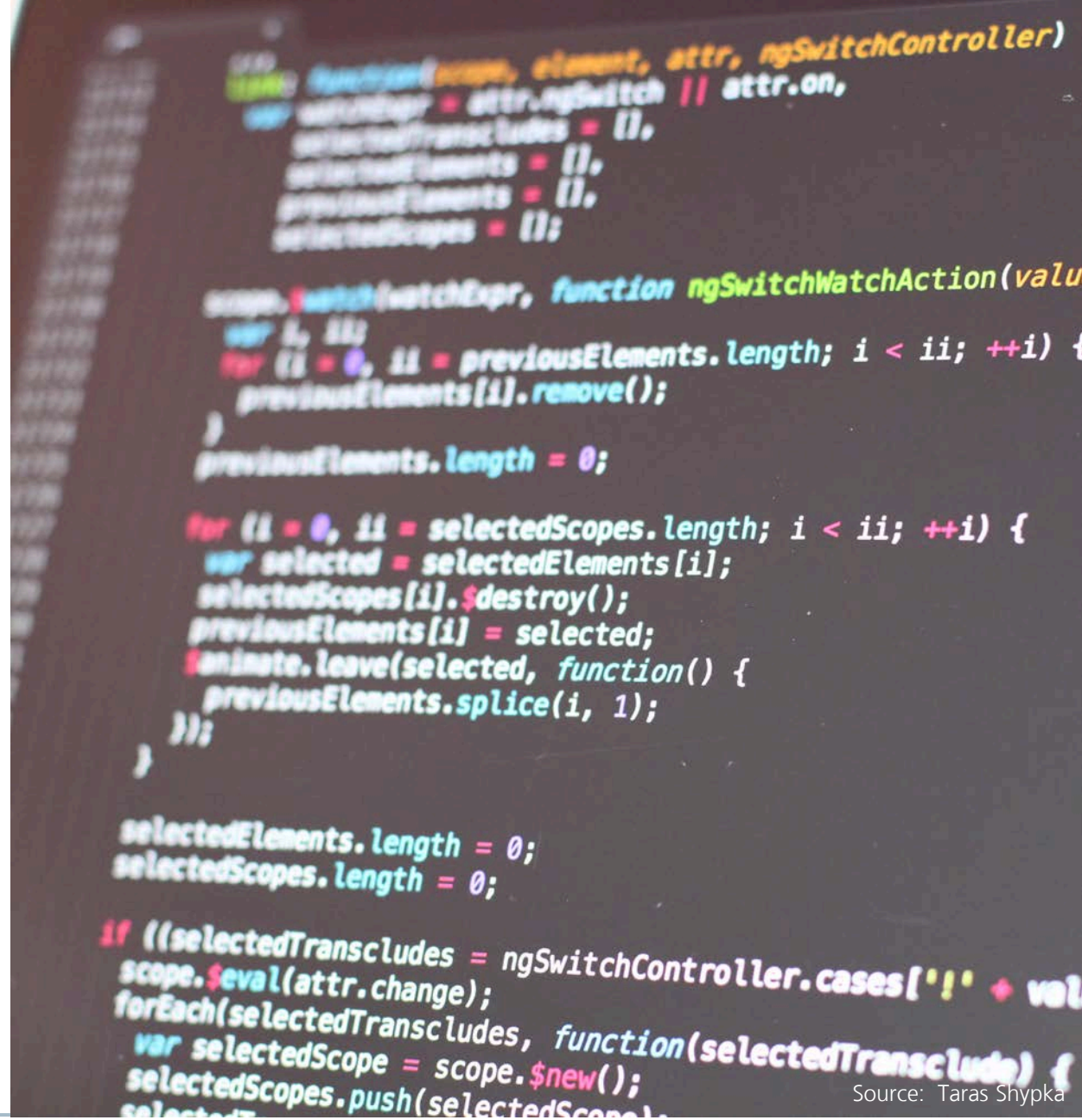
- Software-defined radio modem
- Monitoring and control utilities for payload

Space segment

- Real-time operating system running on LEON3FT
- Monitor and control endpoints
- Communication experiment

Integration into one image

- FPGA design and flight SW form golden configuration item



Source: Taras Shypka

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Automated Tests

CI/CD in Space

Software tests

Hardware tests

- Abstract test specification
- Automated setup, measurement and verification of results with
  - Several RF measurement devices and sources
  - Power supply tester, emulating HPCs and BSMs
  - Fully qualified ground reference model in TVAC
- Creation of LaTeX test report

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{
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        },
```

Continuous Integration in Space

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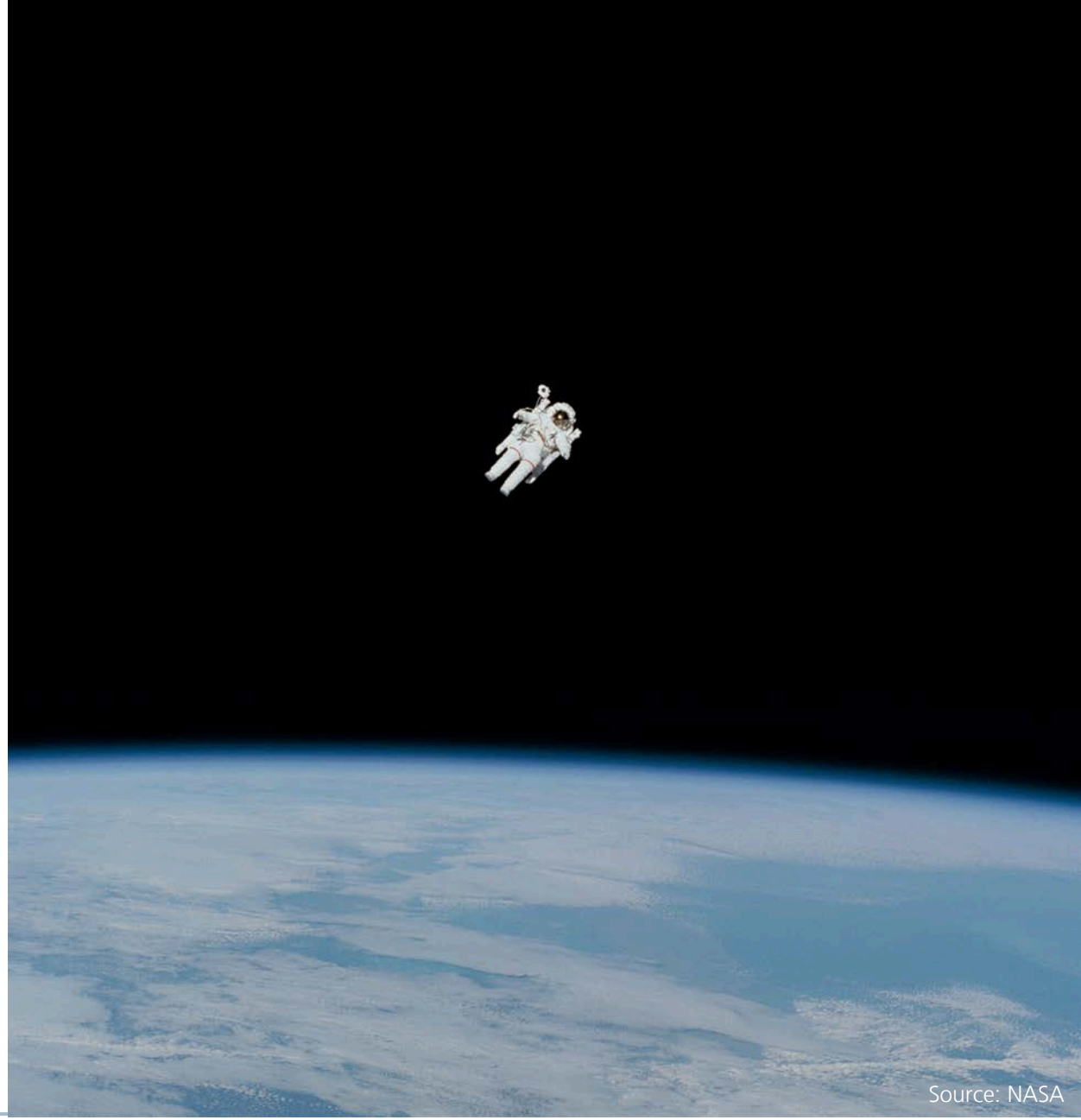
- Next Steps and Applications

Deployment in Space

CI/CD in Space

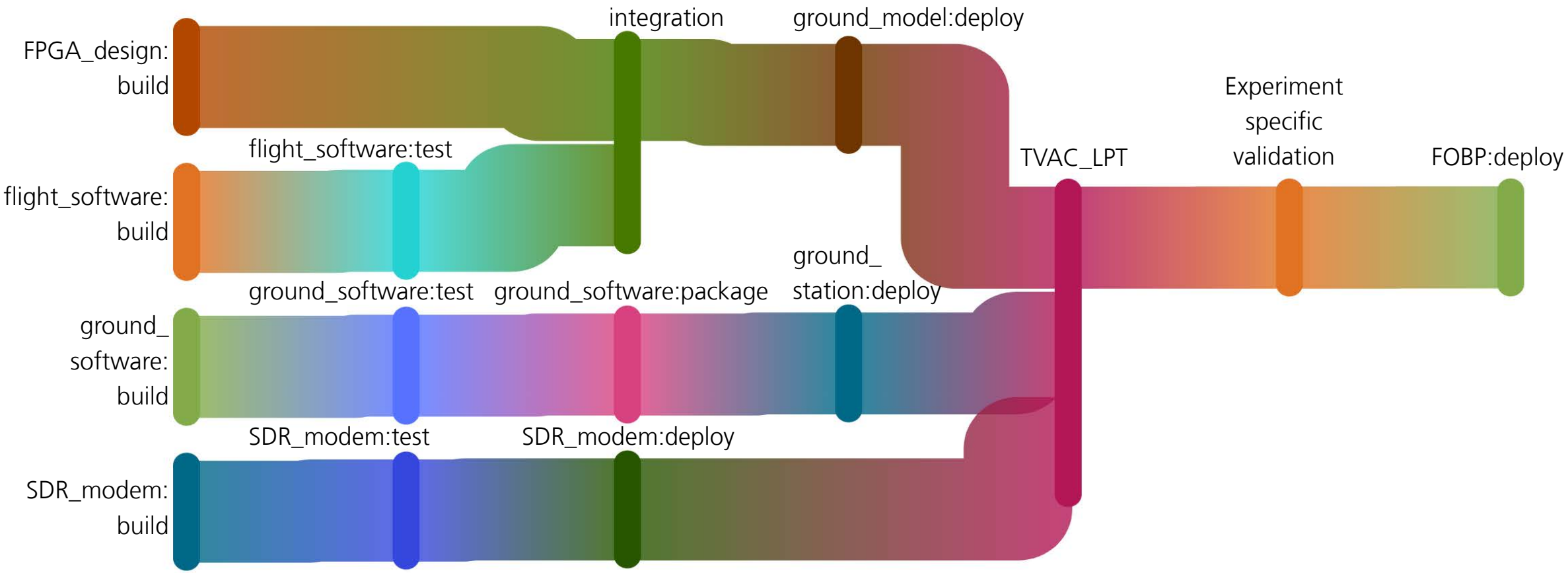
- Receive design updates fast over the air through in-band telemetry and telecommand link
- Reconfigure Virtex5-QV per channel
- Reboot with upgraded FPGA design and software under one minute
- Separate software update possible



Source: NASA

FOBP Pipeline

CI/CD in Space



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Next Steps
H2Sat and FOBP

- Own ground stations
  - Fraunhofer IIS (FOBP only)
  - German Aerospace Center (DLR)
- Launch with last Ariane 5
- In-orbit verification
- Preparation of experiments
- Attracting further experiment partners

Source: ESA/CNES/Arianespace

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Future Applications

FOBP

- Latest communication standards
- 5G over satellite
- Radiation monitoring
- Updates at run-time
- Multi-user systems
- GEO relay for LEO satellites (GeReLEO)
- IoT over satellite (Sat-IoT)
- New scenarios for mobile users
- …

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50 YB 1811

The Satellite Communication Laboratory in Space

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http://fobp.space

Source: Fraunhofer IIS

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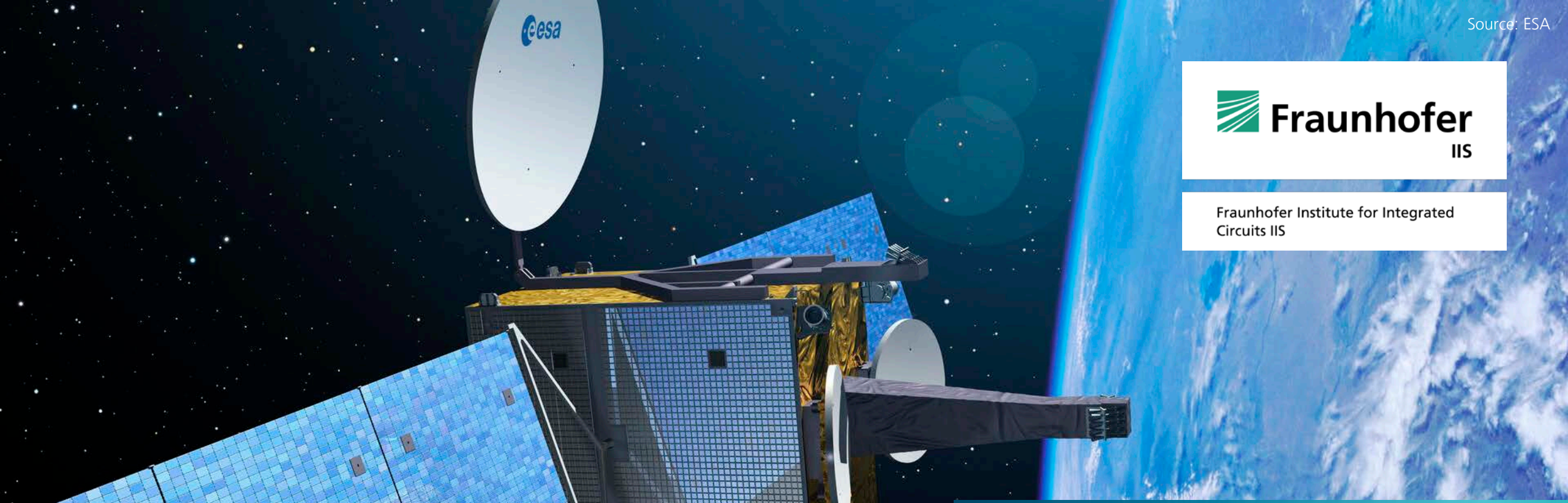

Source: ESA

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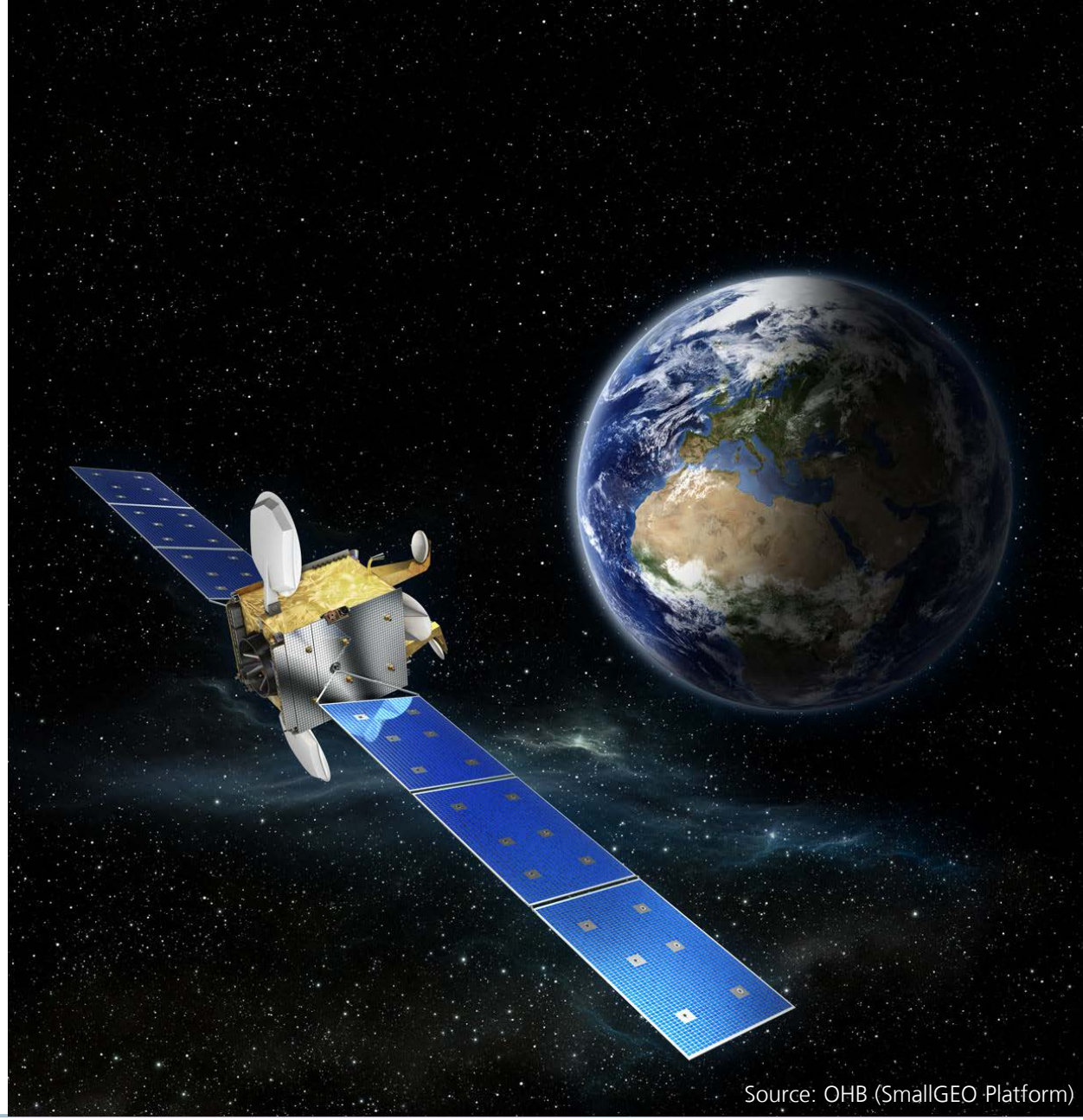
http://fobp.space

Overview

Fraunhofer On-Board Processor (FOBP)

Heinrich Hertz satellite mission goals

- Evaluation of new space grade technology
- Experiments for new communication, antenna and satellite technologies
- Preserving and expanding the ability of German industry to independently design, build and launch communication satellites
- Lifetime: 10-15 years
- Two independent beams and channels in Ka band

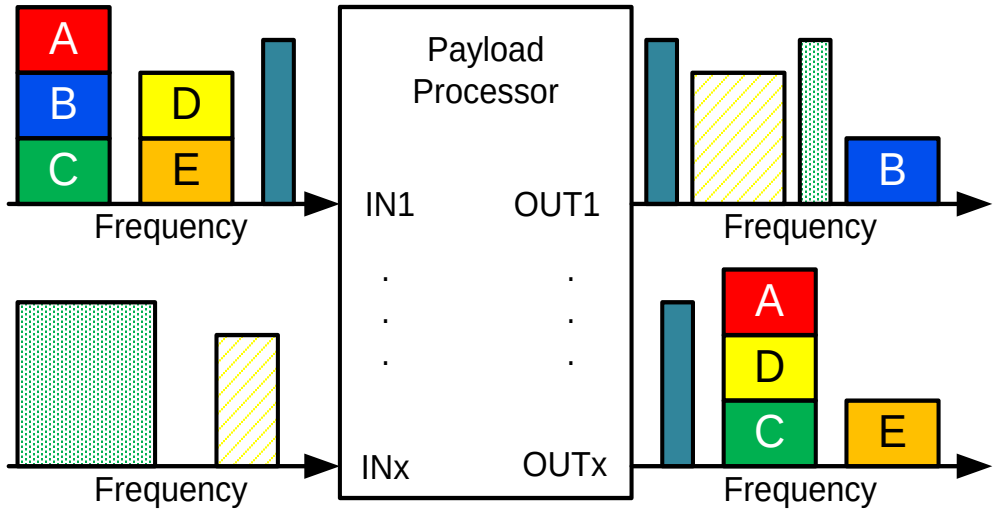


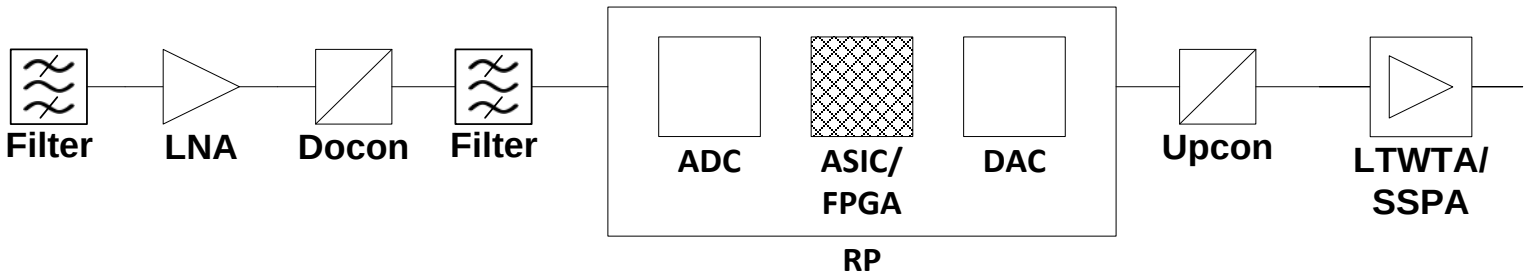
Source: OHB (SmallGEO Platform)

On-Board Signal Processing

FOBP

- Flexible signal processing and signal regeneration
- Higher-layer data processing (e.g. IP based)
- On-board switching and routing (packet based)
- Source coding





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