SpaceWire-RT Publishable Summary for 2nd Reporting Period

The trend towards "Operationally Responsive Space", where spacecraft can be rapidly assembled, configured and deployed, to meet specific mission needs, e.g. disaster support, requires flexible on board communication networks with plug-and-play capability. The growing autonomy of scientific missions to remote planets requires networks that are robust and durable, able to recover from transitory errors and faults automatically. The importance of spacecraft mass reduction motivates the sharing of networks for payload data-handling and avionics. Avionics and robotics impose requirements on network responsiveness and determinism. Increasing international collaboration on scientific and Earth observation spacecraft requires standard network technology where a component developed by one nation will interoperate effectively with equipment developed by another. **SpaceWire-RT**, a project funded under the EU's Seventh Framework Program (FP7), aims to fulfil these demanding requirements with a flexible, robust, responsive, deterministic and durable standard network technology that is able to support both avionics and payload data-handling applications.

SpaceWire is a very successful first step in this direction, providing networking technology for payload data-handling on over 30 major space missions. It falls short, however, of the requirements for avionics systems.

SpaceFibre is a very high-speed serial data-link currently being developed by the European Space Agency (ESA) which is intended for use in data-handling networks for high data-rate payloads. SpaceFibre is able to operate over fibre optic and copper cable and support data rates of 2 Gbit/s in the near future and up to 6 Gbit/s long-term. It aims to complement the capabilities of the widely used SpaceWire onboard networking standard: improving the data rate by a factor of 10, reducing the cable mass by a factor of four and providing galvanic isolation. SpaceFibre aims to support Quality of Service (QoS) along with fault detection, isolation and recovery (FDIR). An important feature of SpaceFibre is that it transfers SpaceWire packets, so that several SpaceWire links can be easily multiplexed over a single SpaceWire link, and so application software designed for SpaceWire can operate over SpaceFibre.

A QoS layer is needed for SpaceWire and SpaceFibre to support mixed avionics and data-handling applications. SpaceWire-RT will: use virtual channels to provide a variety of QoS; provide broadcast and multicast capability; support extremely low latency time and out-of band signalling; and incorporate novel fault detection, isolation and recovery methods. The network will be fully responsible for information transfer, decoupling application and data transfer.

The creation of this technology will substantially strengthen collaborative bonds between the Russian and European organisations involved in the research, and lead to technology of vital importance for future space missions.

The principle aims of SpaceWire-RT are:

- Support all or most spacecraft onboard communication requirements:
  - Instrument interfacing
  - Device and sub-system networking
  - Inter-processor communications
  - Gathering housekeeping information
  - Deterministic command and control
  - Time distribution
  - Sub-system synchronisation
  - Event signalling

- Provide a coherent set of protocols covering:
  - Full range of operational speeds (1 Mbit/s to 20 Gbit/s)
  - Full range of operational distances (0.1 m to 100 m)
  - Using a range of physical media and signals

The technical work began with WP 1 and 2. WP1 (Spacecraft Avionics & Payload Use Cases) focused on the requirements and use cases for spacecraft onboard communication networks for both payload applications and avionics. Astrium GmbH and Submicron gathered requirements for avionics networks including reliability, fault tolerance, fault isolation, performance, responsiveness and determinism from spacecraft manufacturers and spacecraft equipment suppliers across Europe and Russia. A series of use cases was explored covering a diverse set of avionics and payload applications. These requirements formed the basis for the technical capabilities of the SpaceWire-RT network technology.

WP2 (Concept and Specification) reviewed existing networking technology including commercial technologies, SpaceWire, SpaceFibre and other onboard technologies. A set of evaluation criteria were derived from the requirements of WP1 and the candidate networking concepts traded-off against one another. SpaceFibre was selected as the baseline technology for SpaceWire-RT. Several areas of SpaceFibre which required substantial further research and development were identified for investigation in the SpaceWire-RT project including QoS, FDIR and the network layer. Concepts were devised that met the requirements form WP1 and a specification was produced by the University of Dundee.

In WP3 (Simulation and Validation) simulation models covering key aspects of SpaceWire-RT were designed by SUAI and used to evaluate the proposed SpaceWire-RT solution. The simulation models were developed in SDL and used to run various validation scenarios. The results of the simulation were used to update the SpaceWire-RT specification and to inform the VHDL IP Core Development and ASIC Feasibility activities.

WP4 (VHDL IP Core Prototype) began with the architectural design of the SpaceWire-RT IP Core based on information from the outline SpaceWire-RT specification (WP2). Once the architectural design was ready the design and development of the VHDL IP core and associated test bench was carried out followed by testing. The IP core was implemented in an FPGA by the University of Dundee and tested extensively. The results were presented to the SpaceWire Working Group and the SpaceWire-RT specification updated.

WP5 (ASIC Feasibility) covered the review and evaluation of suitable ASIC technologies for SpaceWire-RT implementation, the procurement of suitable ASIC libraries and initial design and simulation work. Owing to the expense of ASICs, device manufacture was beyond the scope of the project, however the principal risk areas with an ASIC development were investigated and the feasibility of ASIC implementation assessed by ELVEES.

The results from all the previous work packages were fed into WP6 (Standard Draft) where a draft standard for SpaceWire-RT was written by the University of Dundee with all partners involved in review of the document. The SpaceWire-RT standard built on the SpaceFibre specification, adding in the quality and network layers. The draft standard was presented to the SpaceWire Working Group and feedback used to improve the document. SUAI translated the standard into Russian.

In conclusion, the SpaceWire-RT objectives have been fully addressed:

- A comprehensive set of requirements and use cases for spacecraft onboard networking has been produced.

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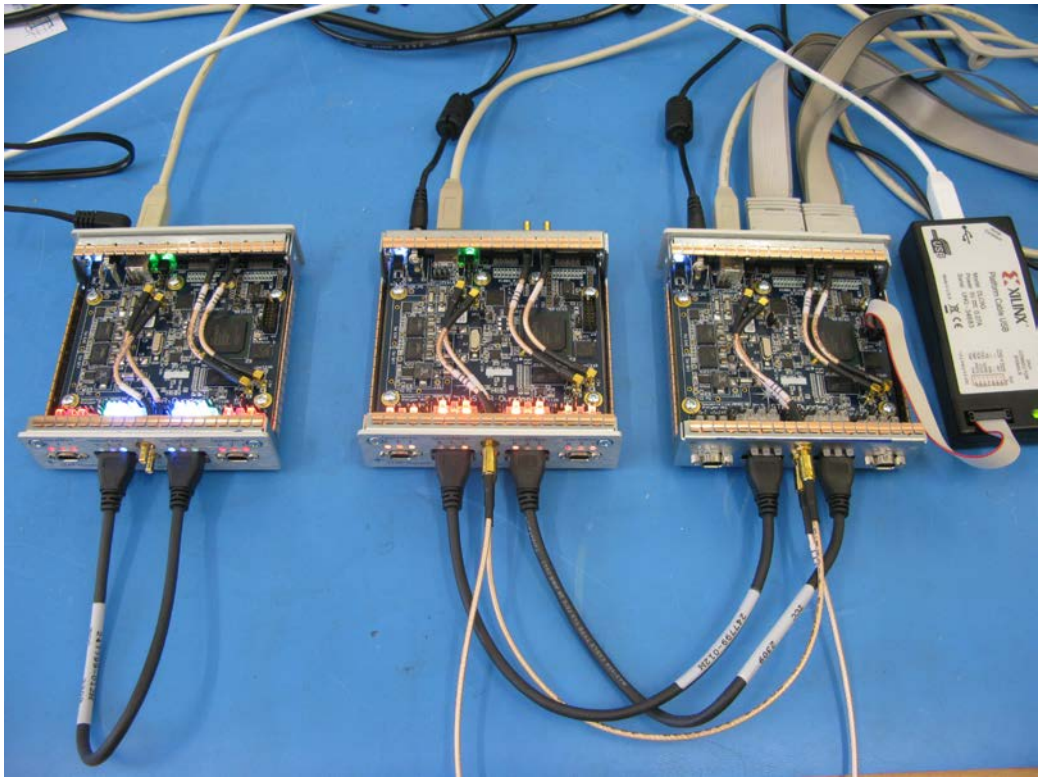
- The SpaceFibre networking technology has been selected as the basis for SpaceWire-RT and essential, innovative QoS and FDIR capabilities designed to complement SpaceFibre.
- A baseline network layer for SpaceFibre has been devised.
- A validated SpaceWire-RT specification has been written with important, novel features of SpaceWire-RT networks tested using SDL and SystemC models.
- The feasibility of implementation in space qualifiable ASIC technologies has been assessed and demonstrated through simulation.
- The results of the SpaceWire-RT study have been disseminated to the European and Russian space industries and to the international space community.
- The SpaceWire-RT technology has been reviewed at various points during the two years of the SpaceWire-RT project by the International SpaceWire Working Group.
- A draft standard document for SpaceWire-RT has been produced.



Prototype SpaceWire-RT Equipment

SpaceWire is a European technology used by the world's space agencies and space industry on many spacecraft. The SpaceWire-RT project aims to take this technology to the next level, by providing an enhanced SpaceWire network technology that provides quality of service capabilities suitable for spacecraft data-handling and control applications, enabling it to support rapid spacecraft assembly and also making it applicable to other applications.

The creation of this technology will substantially strengthen collaborative bonds between the Russian and European organisations involved in the research, and lead to technology of vital importance for future space missions.

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