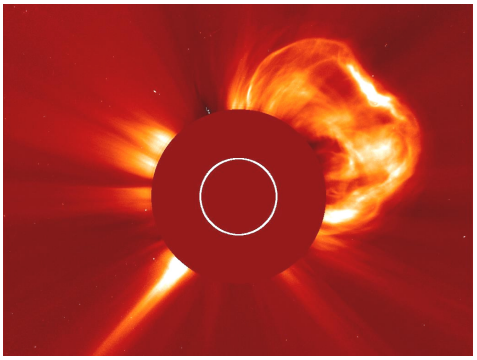
How, and why, 4Links enables you to build *Networks that Work*

4Links 4Links' staff have a longer continuous association with the technology that has evolved to SpaceWire than any other organization. 4Links' rack-mounted test equipment family for SpaceWire has quickly resolved many problems that simulation and other test methods had previously failed to resolve, and has detected many design issues that had previously escaped detection. Although widely used, in more than 25 countries, not a single bug has been reported in the SpaceWire design of these 4Links products since they were first shipped to customers in June 2004. One of many customer plaudits is "4Links products are good value, very accurate and very reliable".

SpaceWire SpaceWire is a simple, modular, flexible and scalable networking technology that has been issued as a standard by the European Space Agency, ESA, and widely adopted worldwide for the harsh environment of Space. NASA, JAXA (Japan) and Roscosmos (Russia), and many other space agencies, companies and institutions have endorsed SpaceWire and are designing it in to their new satellites.

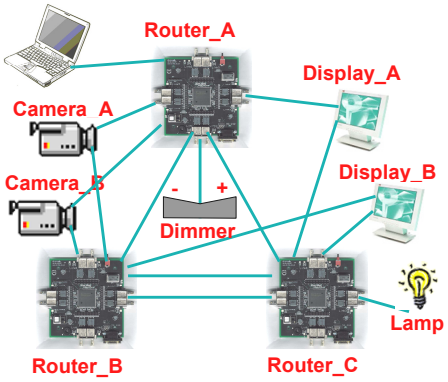
Technology evolution SpaceWire has evolved from technology originally used on the Inmos transputer. This was a chip, designed in the 1980s, which combined a processor, memory, and simple communications, all onto a single chip. The chip was used on a number of satellites, mostly in Europe but also in countries on other continents. A particular example is the joint ESA/NASA Solar and Heliospheric Observatory, SOHO, which is still sending back beautiful and informative images of solar activity many years beyond its expected life.



NASA – SOHO View of corona mass ejection (nasa.gov/mission_pages/sunearth/news/gallery/20120127-cme.html)

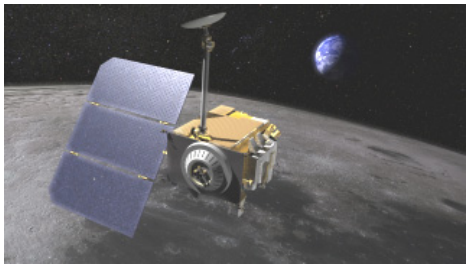
IEEE Standard When a new version of the transputer links was designed in the late 1980s, with a simple packet protocol and running at 100Mbits/s or faster, 4Links' Founder proposed a standard based on these links. His colleagues at Inmos developed this proposal into an IEEE standard, and there are many satellites flying that use this standard, including Mars and Venus Express from ESA, the Solar Dynamics Observatory from NASA, and the commercial Inmarsat4 satellites that provide a 'broadband global area network'.

SpaceWire Standard With such wide use of the IEEE standard for space use, it was natural for the space industry to customize the standard, and the SpaceWire standard was published by ESA in 2003. At the same time, 4Links demonstrated the performance, simple configurability, and potential low cost of SpaceWire, together with a fault-tolerance that would be unachievable with many of the alternative serial interface technologies. This demonstration convinced both engineers and their managers that SpaceWire could deliver on its promise, and perhaps the majority of spacecraft currently being designed or commissioned incorporate SpaceWire. A mission that is already flying SpaceWire is NASA's Lunar Reconnaissance Orbiter.



The 4Links demo of SpaceWire, showing performance, low-cost, and a fault-tolerant topology that would fail with many other network technologies

4Links contribution 4Links' CTO and a senior engineer, as well as the company's Founder, have deep experience of the transputer, its links, and its design principles. This unique depth of understanding within 4Links has been the foundation of the company's contribution to SpaceWire and thence to the space industry worldwide. Recognition of this contribution has led to a major increase in sales of test equipment and to increasing requests from key industry players, for help in projects, and for SpaceWire components and intellectual property.



NASA Lunar Reconnaissance Orbiter, one of the first missions to fly the SpaceWire standard (LRO7 print 9, credit: Chris Meaney /NASA 2008)

4Links test equipment

Like SpaceWire itself, 4Links provides the qualities of modularity, flexibility and scalability to its test equipment. The products are supplied as a 1U rack mountable hardware platform, with connectors for power, Gbit Ethernet and one or more SpaceWire connectors, together with a memory card which holds the firmware.

4Links platform with 8 SpaceWire ports, with a plugged-in memory card that defines the product function

Stages of a mission life-cycle

The flexibility of the hardware platform + firmware memory card approach means that much of the hardware can be used and reused at all stages of the mission life-cycle. For **breadboards**, a simple interface may be needed to try some experiments with using SpaceWire, or to do simple functional tests. **Engineering and flight models** must be rigorously tested, and an interface with good diagnostics is needed. During **integration and test**, subsystems that appeared to work standalone may not work so well with other subsystems, and it is necessary to monitor the traffic to see which end of the link is responsible for the problem. At all stages, simulation of parts of the system can be useful and SpaceWire infrastructure may be needed.

Synchronization and system test

Several members of the 4Links test equipment family are able to synchronize with other test units, so that time tags in the logs from different units, even when controlled by different computers, can be consistent. This makes it possible to combine log files into a single, consistent record. And with the Absolute Time Interface, this record can be precisely aligned to Time of Year.

Product functions

The table below summarizes the 4Links test equipment products for SpaceWire. For further details, including descriptions of the options, please see the 4Links web site, http://www.4Links.co.uk

Broad function	Product name	Description	Options
SpaceWire interfaces	EtherSpaceLink, ESL	Entry-level interface from Ethernet to one SpaceWire port at a time; can be used with software to test or simulate a subsystem	ER, EW, TT, TC
	Diagnostic SpaceWire Interface, DSI	Interface from Ethernet to up to eight SpaceWire ports active at the same time, with powerful diagnostic options. Can also be used to simulate multiple subsystems	Sync, EI, ER, EW, SO, TT,
SpaceWire simulators	SpaceWire RMAP Responder, SRR	Provides low-latency response, on up to six ports concurrently, to requests of SpaceWire's Remote Memory Access Protocol (RMAP)	Sync, 32K, 64K
	Flexible SpaceWire Router, FSR	Eight-port SpaceWire routing switch, with optional packet statistics	TC, PS
SpaceWire analyzers	Multi-link SpaceWire Analyzer, MSA	Passively monitors up to four SpaceWire links and provides statistics of all characters transferred in each direction	EW
	Multi-link SpaceWire Recorder, MSR	Passively monitors up to four SpaceWire links and sends time-tagged data to be recorded on a PC.	Sync, ER, EW
SpaceWire infrastructure	Absolute Time Interface, ATI	Synchronizes a set of 4Links test equipment to an IRIG time of year reference	Sync
	SpaceWire laboratory cables	Commercial cables, not suitable for flight or for vacuum test, but much more flexible for lab use; available in variety of lengths	length, shield termination

4Links background and affiliations

4Links is a UK SME, founded in 1993, incorporated in 2000, and funded entirely by customer sales. It is a member of the UKSpace SME Forum, formerly ASTOS. It was a member of and contributor to the IEEE 1355 Working Group that also included engineers from Inmos and from Dornier Satelliten Systeme, now part of EADS-Astrium, and has been a long-standing member of and contributor to the SpaceWire Working Group. 4Links is based at Bletchley Park, home of the WW2 code-breakers and home of Colossus, the world's first programmable electronic computer.

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