SciSys Space & Defence

Launching Real-Time CORBA into Space

Motivation and Implementation

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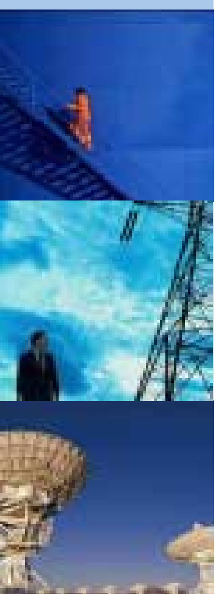
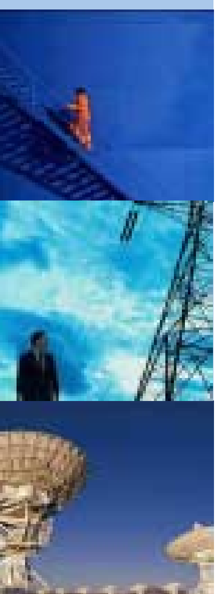
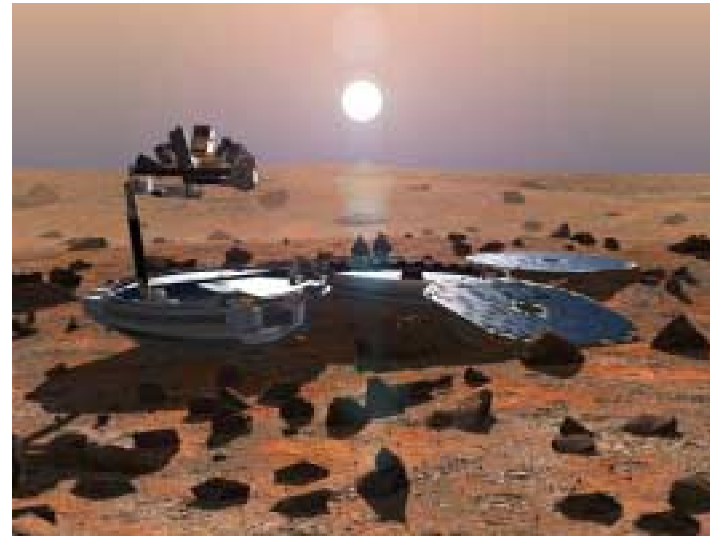


SciSys (Space and Defence) Ltd



- Part of CODASciSys plc, a Systems and Software House founded in 1980
  - 750 staff, 120 of whom work in Space and Defence
- European experts in satellite control centres
  - ESOC, EUMETSAT, EUTELSAT, UK MoD…



All Rights Reserved Beagle 2

- On Board Software (OBS) Group formed in 1996:
  - Flight Software e.g. CryoSat, XMM/Integral and Beagle2
  - Digital Signal Processing e.g. Multi-Mission Imager
  - Advanced Technology Investigations for British National Space Centre (BNSC), European Space Agency (ESA) and UK MoD, e.g.:
    - Intelligent Systems,
    - Formation Flying, Guidance, Navigation and Control (GNC),
    - CORBA, Remote Agents, CCSDS-SOIF

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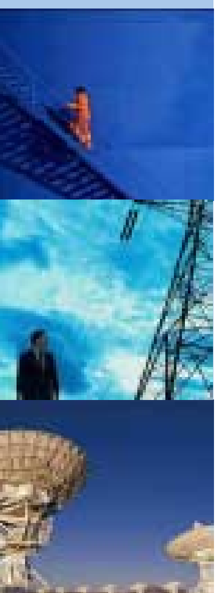
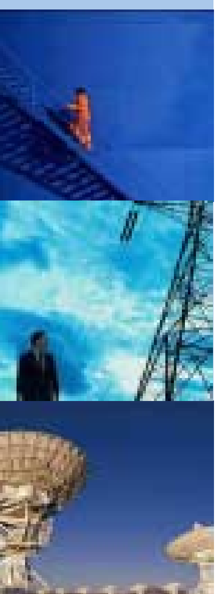
Motivation



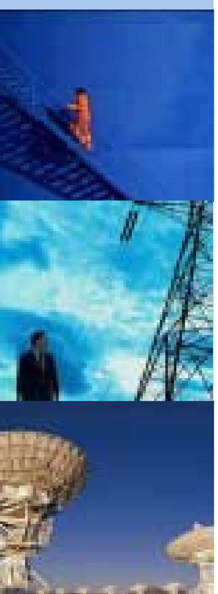
- Trends and Issues in European Space Industry
  - Increasing diversity and complexity of missions
  - Increased reliance with on-board autonomy
  - Increased use of ground automation
  - Common software kernels (space, ground)
  - Falling budgets (want more for less...)
  - Increased role of COTS, Re-use & Open Source...



Motivation

- Emerging requirements for a software framework to solve the following issues:
  - Deployment of technologies that improve mission performance
    - e.g. autonomous on-board scheduling of tasks without direct ground contact
    - e.g. distributed station keeping for multi-sats
  - Increased number of processors used to cope with mission complexity
    - Predictable scheduling of processors, data-buses and combined system becomes complex
  - Reduced costs and risks
    - reduces development and integration effort
    - improved software quality through clear system definition of components that can be proven in isolation
    - Increases flexibility on-board, allowing re-configurations and upgrades
    - enables increased software re-use between missions

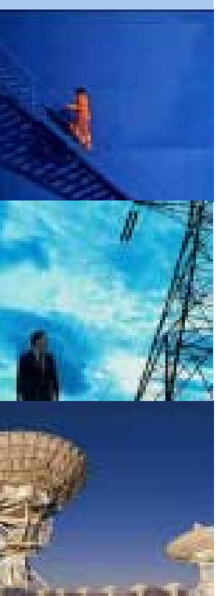
Motivation



- In general, Middleware provides a convenient layer of abstraction to provide a solution to both issues:
  - Design and implement each autonomous function as a discrete, re-usable component
  - Location transparency allows flexible system building during integration, test and flight
- ... but predictable behaviour still required so that performance of control functions on-board spacecraft can be guaranteed

Technologies

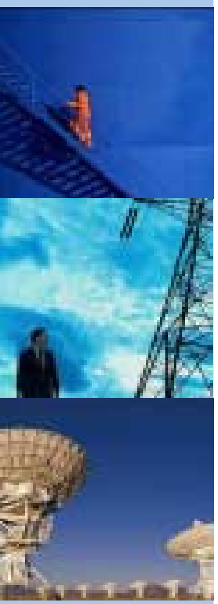
- Sponsored by BNSC and ESA, SciSys have been looking at the application of the Real-Time CORBA standard to provide this middleware abstraction layer:
  - Attractive because it is an open, mature standard with support for a variety of platforms
  - Provides an abstraction above kernel task scheduling (well understood within space community), allowing event-driven software
    - Events are real, asynchronous and possibly external to system (e.g. incoming packet, RTOS timer interrupt, hardware interrupt)



- But need to take account of the existing constraints within the Space environment...

Technologies

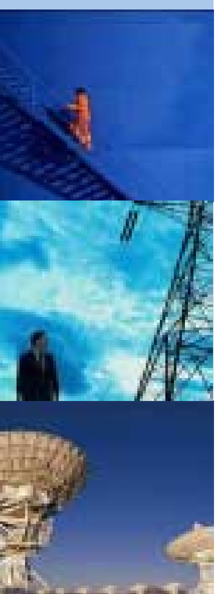
- Resource constrained environment
  - Radiation-tolerant processors with low production runs results in lower performance than current “state-of-the-art”, e.g. 20 MHz
  - Similar issues with memory, e.g. 5-20 Mbytes
  - Communication links:
    - Space links characterised by small bandwidth, long latency, packet errors
    - On-board data buses evolving from 1553 (low bit rate, master-slave bus) to CANbus and SpaceWire (high bit rate network)
    - High number of serial links (analogue, digital pulse and digital discrete)

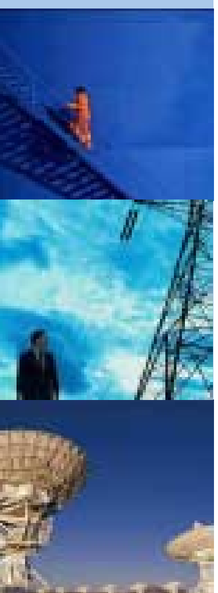


Technologies

- High availability, real-time systems
  - Run-time Environment
    - Ravenscar profile of Ada95, e.g. ORK
    - RTOS, e.g. VxWorks, RTEMS
  - Programming Languages:
    - Ada95 and ANSI C (not C++ or Java!)
  - Predictable response times
    - Rate monotonic scheduling
  - Predictable memory usage
    - Implies not using a heap

- Missions have long life-times
  - Requirement of supplier support for life-time of mission
  - Customers generally requires source-code
  - In-flight remote upgrades only!

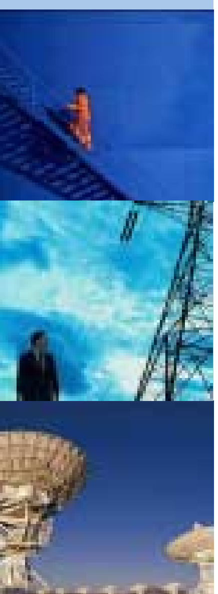




Technologies

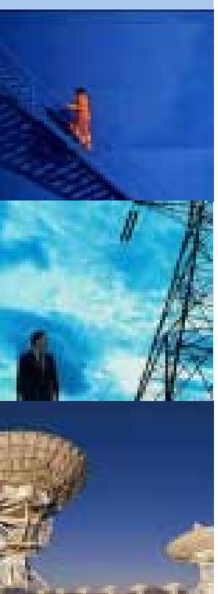
- Communications Protocols:
  - ↳ Use of TCP/IP within spacecraft discounted because of non-deterministic timing characteristics
    - no priority model
  - ↳ CCSDS Spacecraft On-board InterFaces (SOIF)
    - Current standardisation effort within international space community (inc. ESA, NASA, Japan)
    - Layered communications architecture based on OSI model
    - Data Link, Network and Transport Layer service definitions
    - Application Layer service definitions, including...

Technologies



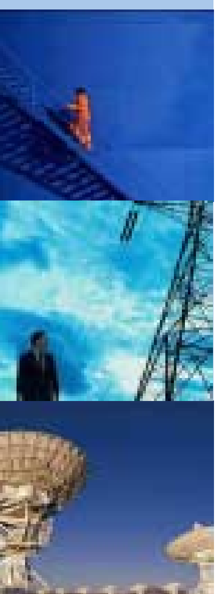
- SOIF Message Transfer Service
  - ➩ Sending of discrete arbitrary-sized messages across connections between distributed applications
  - ➩ Priority ordered delivery, dependant upon lower-layer communication protocols e.g.
    - direct onto SpaceWire network
    - over “SOIF” transport layer protocol (simplified TCP/IP, e.g. SCPS-TP?)
  - ➩ SciSys providing European lead in service specification (with JPL)

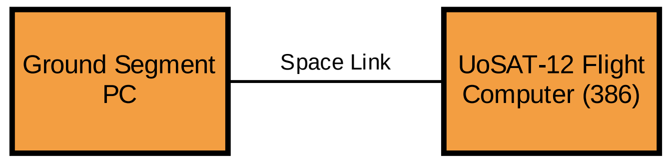
Technologies



- Embedded Real-Time ORB
  - Market survey (2000) found none suitable for embedding in spacecraft
  - SciSys developed prototype ORB – “microORB”
  - IDL-to-C mapping, (Ada95 support under development), Real-Time CORBA specification, variety of OSs (RTEMS, VxWorks, VDK, Linux, POSIX), AMI, IIOP, GIOP mapping to SOIF Message Transfer Service
  - Light-weight Naming and Trader services

Example Applications

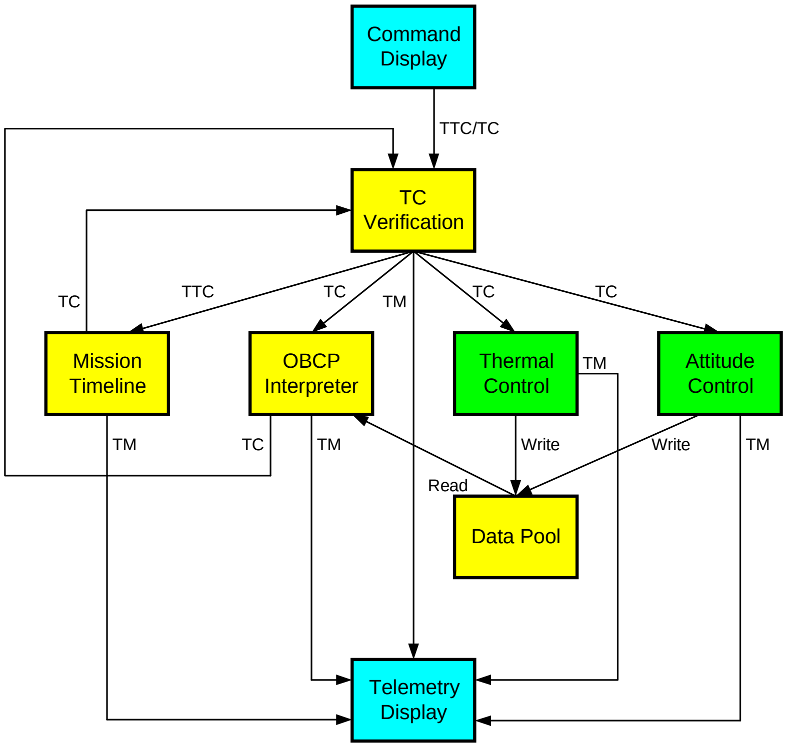


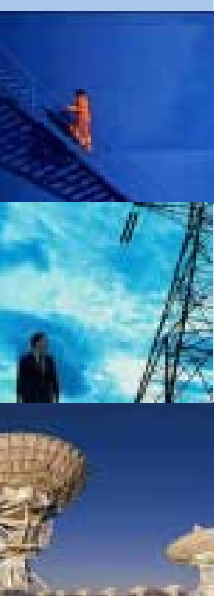


- RATE II
  - BNSC sponsored simple CORBA in Space demonstrator
  - SSTL's UoSAT-12 mini-satellite in LEO
  - TCP/IP over space link to control centre
  - Simple C application using microORB deployed on UoSAT-12 in May 2003
    - Attitude Determination using Fuzzy Logic integrated with UoSAT-12 flight software
  - Communicating over space link using CORBA/IIOP with Windows GUI using ORBacus in control centre

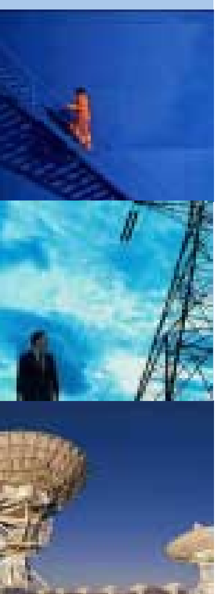
Example Applications

- RAMA
  - ESA CryoSat mission's Data Handling subsystem (written in Ada95) re-engineered as autonomous agents communicating using Real-Time CORBA within a simulated spacecraft
  - ESA-sponsored investigation into deterministic distributed computation model using Real-Time CORBA and SOIF Message Transfer Service
  - Demonstration of operator-driven on-line replacement of an agent (mechanism and effects on predictability)



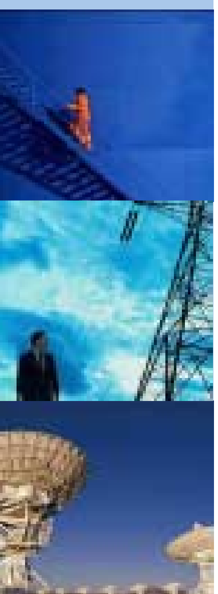


Future Directions



- Fault-tolerant computing
  - Cold/warm-standby processors (e.g. bank of non-rad-hardened to reduce cost)
- Software Engineering process
  - AADL, UML Profile for Schedulability, Performance and Time Specification
- OMG Space Domain Task Force
  - SciSys are the BNSC representatives
  - RFI2 CORBA-based Space Communications

Conclusions



- Trends within Space industry leading to use of real-time and embedded middleware

- RT-CORBA provides many of the characteristics required and is being actively investigated through consideration of issues, prototyping and practical demonstrators