

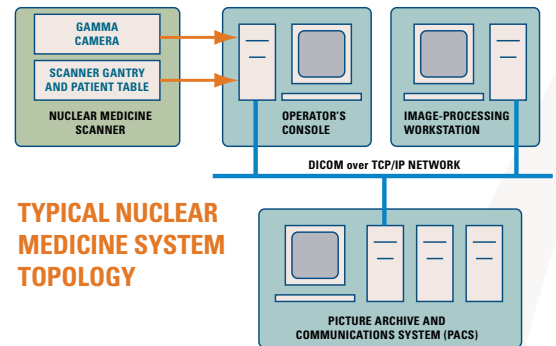
Tactiq's GE Medical Console

Operator console for GE Healthcare nuclear-medicine imaging system

Since 1996, Tactiq (www.tactiq.co.uk) has been developing complex embedded software and an outstanding track record in the medical-systems industry. Tactiq is proud to have GE Healthcare as a major client for over ten years.

Tactiq plays a leading role in developing and supporting GE Healthcare's most successful nuclear medicine imaging system—the GENIE Acquisition system, with LynuxWorks' LynxOS real-time operating system inside.

tactiq



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Nuclear Medicine (NM) imaging has been in use since the 1960s. A radiopharmaceutical injected into, ingested by or inhaled by the patient emits gamma radiation. A sensitive gamma camera detects the radiation emitted from the patient. A computer (operator's console) processes this to form and store an image. Computer technology is used to provide image processing, archiving and network features. Real-time computing allows the undertaking of complex scan types that require the precise real-time positioning of the patient with respect to the gamma camera and synchronisation of the image formation to physiological processes.

Nuclear medicine images biological function not anatomical structure. NM images are typically "fuzzy" compared to other imaging procedures but the functional information is quantitative and complementary to other techniques. The most widespread applications are bone, cardiac, lung and renal imaging. Image processing is used to extract data such as the ejection fraction of the heart, lung capacity (both gas and blood flow) and kidney function.

Bone imaging is used to locate joint wear, hairline fractures and bone cancer.

GE Healthcare (www.gehealthcare.com) is the world leader in the provision of medical imaging products including X-ray, ultrasound, CT, MRI, PET and nuclear medicine. GE Healthcare is an \$18bn business.

The Tactiq (formerly Atalanta) team are the design architects behind GENIE Acquisition, GE's most successful NM operator's console. Tactiq continues to play the lead role in the development of GENIE Acquisition. This document describes key aspects of the development process and the roles played by Tactiq.

GENIE Acquisition

GENIE Acquisition is a system control and imaging application running on the LynxOS® real-time operating system. The hardware platform is an "off-the-shelf" PC. GENIE Acquisition provides gamma image acquisition, sophisticated motion control and an operator's interface to nuclear-medicine imaging systems. This enables a technologist to set up and execute a variety of NM scans.

Image data can be easily transmitted using DICOM across a hospital network to a variety of destinations including image processing workstations or Picture Archive and Communications Systems (PACS).

GENIE Acquisition's primary functions:

- User interface to set up and execute patient scans
- Scanner gantry calibration and real-time motion control
- Gamma camera data acquisition, image correction and image framing
- Gamma camera control, calibration and image quality assurance
- Image display during acquisition
- Display of previously acquired data for review
- DICOM network functions for sending images to PACS or workstations and fetching patient schedule information

GENIE Acquisition is regarded by many inside and outside GE Healthcare as the "gold standard" for ease of use, reliabil-

ity and flexibility. Since its introduction in 1996, over 2000 have been shipped with a range of NM systems. In 2003 over 350 GENIE Acquisition systems were shipped from manufacturing in Haifa, Israel.

Tactiq's role in GENIE Acquisition development

The Tactiq team are the architects and core development team behind the highly successful GENIE Acquisition system.

For over 10 years Tactiq's project managers and engineers have lead and worked with engineering teams in the UK, USA, Denmark, India and most recently Israel. Highly developed collaborative engineering skills and experience continue to ensure the smooth execution of GENIE Acquisition projects regardless of the geographic location of GE's engineering teams.

Tactiq continues to play a central role in ongoing development and support, working closely with GE Healthcare's

engineers based in Haifa, Israel and with service engineers worldwide.

Product development process: Understanding requirements

Clearly documented product requirements are essential to ensure that all interested parties have a common understanding of the performance, features and cost targets. This stage of the product life cycle offers a low-cost opportunity to make changes that affect product specifications.

Tactiq analysed and documented GENIE Acquisition requirements encompassing:

- Control and calibration of a range of NM scanner gantries
- Control and calibration of a range of NM gamma cameras
- Integration with hospital medical imaging networks
- NM technologists' (operators') needs
- Doctors' needs for study types and image quality
- Service engineers' needs
- Hospital administration needs for scan times, reliability, safety, cost and training times
- GE's needs for marketability, reliability, safety, cost and time to market
- Future enhancements and maintenance

Product development process: Design

A good design is crucial to ensure that the finished product meets requirements and is flexible enough to accommodate changes that are inevitable during the product lifecycle. The quality of a design has a significant influence on product lifetime and return on investment.

GE Healthcare's target for GENIE Acquisition's production life was for 5 to 10 years. Tactiq applied a wide range of expertise and experience to design a robust framework within which it is

easy to add new features and to support a wide range of different gamma cameras and mechanical systems. The result is a product that looks as polished and remains as reliable today as it did 8 years ago. GENIE Acquisition now supports nine different nuclear medicine hardware systems with 95% common software. This is producing substantial benefits in product reliability, speed of development, validation and maintenance.

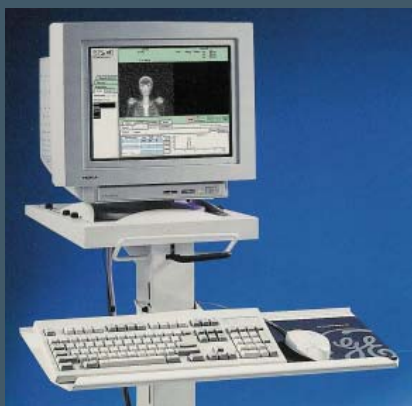
Object-oriented design techniques are used extensively throughout GENIE Acquisition. MagicDraw™ computer-aided design tools are used for much of requirements capture and OO design.

System and subsystem testing were considered early in the design process. Tools and an environment were created to allow simulated testing as an intrinsic part of GENIE Acquisition development. The ability to perform simulated testing accelerates and simplifies subsystem testing and is a significant factor in producing excellent overall system reliability.

The Tactiq team designed the very successful GENIE Acquisition graphical user interface. User task analysis and focus on customers' needs resulted in a user interface that was ground-breaking in its ease of use. Operator training time for a NM technologist was reduced from one week (previous Starcam™ system) to less than half a day, yet the ability to perform complex scan types was not compromised.

Tactiq developed the embedded database, DICOM networking, real-time image display and acquisition software. From 1997 Tactiq has maintained and enhanced the gantry motion control software and the DSP software that performs real-time gamma event correction.

The GENIE Acquisition Operators Console controls the NM scanner system and provides a graphical user interface for operator interaction, including scan set up, image review and network image transfer.



In 2001 Tactiq re-designed the gamma camera interface electronics to support a pre-existing model of gamma camera, allowing field upgrades of the acquisition computer.

Implementation

GENIE Acquisition is implemented principally in C and C++. The majority of the user interface is implemented in C++ with most of the underlying software written in C.

GENIE Acquisition operates on LynxOS, a fully featured UNIX®-like operating system with a deterministic, hard real-time kernel. The host LynxOS software is built, tested and debugged using GNU tools, Make, BASH and CShell. DSP software is developed in assembler and built into downloadable executables using Analog Devices tools. A CVS (source version control) server is used to manage software versions. The flexibility of CVS enables the Tactiq team to work concurrently with engineers around the world on the same software application.

CVS is used as a source version control system. This is core to managing collaborative development work. It is not uncommon for GENIE Acquisition releases to be developed by a team split between the UK and Israel.

Testing and validation

Tactiq has incorporated powerful simulation into GENIE Acquisition. This allows for extensive testing without the need for a complete NM system. An emphasis on early testing improves the quality and reliability of software prior to integration testing.

Simulation allows over 70% of integration to be undertaken without the need for connection to an NM system. Final integration testing, prior to system validation, is normally undertaken at GE's facility in Israel. Remote system

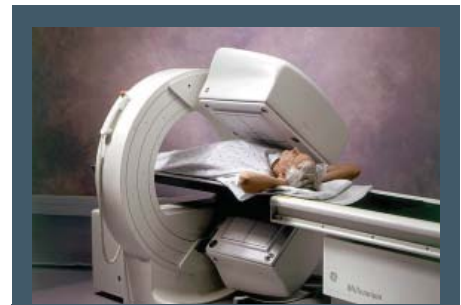
access tools allow engineers in the UK to access NM systems in Israel either for test and debug. These tools enable engineers in the UK to use an NM system in Israel while running the user interface on a PC in the UK. It is also possible to access the system via remote login to monitor system status, retrieve error logs and modify configuration parameters. Restrictions on the remote operation of scanner motion ensure safety. In the case of large releases that include significant new features a Tactiq engineer travels to Israel for 1 to 2 weeks to accelerate the integration process. Final validation is undertaken in Israel with support and guidance from the Tactiq team in the UK. Remote access is once again crucial to support the validation process.

Support

GENIE Acquisition's introduction in 1997, Tactiq has provided worldwide technical support, primarily through a combination of telephone and remote system access from the UK. Occasionally Tactiq's engineers travel to hospitals around the world, providing engineering representation for GE Healthcare. Breadth of knowledge enables Tactiq to identify and correct problems beyond the remit of the GENIE Acquisition software. A personable demeanour and the rapid correction of faults results in improved customer satisfaction. Tactiq has received much praise from GE Healthcare for its professionalism and effective approach to correcting technical issues while on a customer's site, demonstrating Tactiq's full product lifecycle expertise and commitment to client satisfaction.

Training

Recognised by GE Healthcare as a leader in the development of advanced embedded computer systems, Tactiq is regarded as such a world-class source of knowledge. Tactiq has prepared and presented training material to GE



GE Healthcare's "MG" Nuclear Medicine Imaging System is a very popular variable-geometry, dual-gamma-camera imaging system with approximately 1300 systems installed worldwide.

Healthcare personnel in the USA and Israel to communicate a clear understanding of the design and implementation philosophy that is fundamental to GENIE Acquisition's success. This helps ensure that engineers joining the GENIE Acquisition team design and implement software that does not compromise the reliability and maintainability of GENIE Acquisition.

Looking at the bigger picture

An in-depth knowledge of embedded systems technology and nuclear medicine combined with world-class collaborative engineering skills has enabled Tactiq to make many significant contributions to GE Healthcare's nuclear medicine program. Tactiq has identified and researched several opportunities to add key new features or reduce product cost. The most recent of these is currently underway and expected to save GE Healthcare over \$1.1m per year. The ROI in the first year alone is estimated at 4:1. Looking at the big picture and focussing on customer needs generates real benefits for Tactiq's clients beyond the rapid development of high-quality products.

GENIE development history

1993-96: Prior to Tactiq's (formerly Atalanta) formation, our engineers played a central role in the design and development of GENIE Acquisition going back to the start of the project in 1993. The dual project goals of low cost and ease of use were achieved using off-the-shelf PC hardware running a full-featured, real-time UNIX-like operating system (LynxOS) that allowed hard real-time data acquisition to share a single CPU with a sophisticated, intuitive graphical user interface. GENIE Acquisition R1.0 supported two single detector systems and one dual detector system using common software. The first clinical systems were delivered on time, prior to SNM '96.

1997-98: Support for a compact, variable geometry, dual detector MG system was added and state-of-the-art attenuation correction with interleaved tomographic scans on Optima systems. The software infrastructure was extended to improve configurability and maximize software commonality. MG is GEMS best selling NM camera today.

1998-9: DICOM networking extended to support sending data to Xpert processing station. A flexible networking infrastructure was implemented so that acquired data could be repackaged and optionally corrected to meet the needs of the destination station.

1999: Automatic body contouring (ABC) and attenuation correction (AC) were added for MG systems. ABC required real-time radial motion control of both detectors for tomographic and whole body scans in response to multiple sensor inputs. AC required synchronisation of transmission source motion with acquired event data. Real-time event processing (DSP assembler) was extensively extended to support transmission scanning. MG ABC and AC are sold as options and can be field upgraded.

2000: DICOM Worklist support added allowing scheduled patient and scan information to be retrieved from a HIS/RIS. Scheduled scans are matched to GEMS or user-defined procedures, making Worklist scan set-up completely automatic. Acquired image series can be automatically sent to multiple destinations. The GENIE Acquisition Worklist feature has been very well received by end users for its ease of use and seamless integration within the user interface.

2000-01: Developed GENIE Acquisition upgrade for XC/T and XR/T installed base systems to replace previous generation acquisition console, reducing service costs and providing opportunities for new equipment sales. Customers benefit from GENIE Acquisition ease of use and DICOM connectivity. Detector control and corrections software was re-written to simplify addition of new detector types. Detector signal conditioning hardware was redesigned to operate with multiple detector types. Programmable logic and DSP software was modified to process events from

X series detectors. Tactiq co-ordinated and supported external evaluation for the first customer system. Optimised GENIE Acquisition calibration algorithms improve serviceability and reduce downtime. Many upgrade sites have reported improved image quality.

2001-02: Support of elliptical tomographic scans on MG in cardiac geometry required positioning multiple axes at each view. Tomographic scan set up optimisations and positioning accuracy improvements benefited all system types.

2002: DICOM Send extended to support Storage Commitment and image transfer to Vision processing station. Storage commitment allows a processing station or archive device to take responsibility for the data.system types.

2002-03: Tactiq identified large cost-saving opportunity for CSE detectors, updating detector electronics and replacing proprietary PCI adapter with standard Ethernet interface. Developed detailed business case to help GEMS Haifa secure VCP funding. EDI implemented as a joint software and hardware project between Tactiq and GEMS Haifa.

2003: DICOM Secondary (image) Capture. GE Common User Interface (CUI). Service Enhancements Package. Initiation of automatic image processing of acquired data after automatically sending data to Integra Workstation ("Ignite" feature). Broadcom network device driver for LynxOS operating system.

2004: GENIE Acquisition R4.0 is released with the new "blue" look user interface that is now GE CUI compliant. GENIE Acquisition sales remain strong at over 300 units per annum.

2006: GENIE Acquisition R4.5 released supporting new EDI detector variant with Ethernet interface and real-time event framing under LynxOS.

2007: GENIE Acquisition R4.6 released with improved service and diagnostic tools.

GENIE Function	Language
User Interface	C++
Networking	C
Acquisition engine	C
Embedded database	C
Gantry control	C
Gamma camera control	C and DSP assembler
Image correction and framing	C and DSP assembler



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