II. OPERATION AND DEVELOPMENT OF ATLAS

OVERVIEW

Highlights of the operation of the Argonne Tandem Linear Accelerator System (ATLAS), a DOE national user facility, and related accelerator physics R&D projects are described in this chapter. ATLAS is funded to provide heavy-ion beams for basic research in nuclear physics but also serves other areas of research and development, including material science. In addition ATLAS has a rich program in developing the tools of accelerator mass spectroscopy (AMS) applied to wide ranging research programs such as oceanography, nuclear physics, astrophysics and geology. Over half of the beam time is allocated to experiments for which the spokesperson is an outside user. Recent ATLAS operating performance and related development projects are described in the next section. ATLAS personnel are also involved in developing technology in support of a future advanced facility, based on ATLAS technologies, for beams of short-lived nuclei. Projects related to the Rare Isotope Accelerator (RIA) Facility are described in the third section below.

ATLAS returned to 7-day/week operation in April, 2003 after operating on a 5-1/3 day/week schedule for over a year due to budgetary pressures. For the full fiscal year, ATLAS provided nearly 5500 hours of beam available for research even with this significant operating constraint. Accelerator availability was excellent, exceeding 96% for the year. Statistics about beam hours and users are given in Table II-1.

ATLAS provides a variety of radioactive species with intensities generally in the range of 10^5 to 10^6 particles per second. This year 14.3% of all beam-time went to radioactive beams. Beams of long-lived species ($T_{1/2}$ > 2 hours) produced at other facilities and placed in the ATLAS tandem ion source and beams of short-lived species produced in-flight by inverse-kinematics reactions are used at ATLAS. See the Heavy-Ion Research section for a summary of recent physics results from experiments using radioactive beams.

Gammasphere returned to ATLAS and the first experiment with it was performed in March 2003.

Table II-1. Summary of ATLAS experiments and user statistics.

	FY2003* (actual)	FY2004 (extrap.)	FY2005 (pred.)
Beam Use for Research (hr)			
Nuclear Physics	4479	5135	5350
Accelerator R & D (RIA & ATLAS)	394	250	250
Accelerator Mass Spectroscopy	452	325	300
Other	165	90	100
Total	5490	5800	6000
Number of Experiments Receiving Beam	46	50	53
Number of Scientists Participating in Research	179	250	250
Institutions Represented			
Universities (U.S.A.)	24	25	26
DOE National Laboratories	5	5	5
Other	26	27	27
Usage of Beam Time (%)			
In-House Staff	52	40	25
Universities (U.S.A.)	22	25	45
Other DOE National Laboratories	6	15	15
Other Institutions	20	20	15
Total	100	100	100

*The extrapolation for FY2004 assumes that limited 7-day operation continues for the remainder of the year. The FY2005 predictions assume sufficient funding for full 7-day operation.

A. OPERATION OF THE ACCELERATOR

(R. C. Pardo, D. Barnett, J. Bogaty, A. Deriy, G. Gribbon, R. Jenkins, A. Krupa, E. Lindert, A. McCormick, S. McDonald, F. H. Munson, Jr., D. R. Phillips, D. Quock, A. Ruthenberg, R. H. Scott, S. Sharamentov, J. R. Specht, P. Strickhorn, R. C. Vondrasek, L. Weber, G. P. Zinkann)

a.1. Operations Summary.

ATLAS provided a total of 36 different isotopes for research in FY2003, the same as in FY2002. The distribution of species is shown in Figure II-1. The calcium isotopes were the most popular beams for FY2003 and only 25% of beam time was for isotopes heavier than the nickel isotopes.

A revision to the ATLAS SAD was approved last year allowing more flexibility in modifying operating parameters. A study of allowed radiation levels and ATLAS facility shielding was undertaken following the SAD approval and resulted in a recommendation to allow higher maximum radiation levels in locked areas of the facility, (but with some additional shielding enhancements in specific parts of ATLAS). These recommendations were approved and the maximum radiation levels allowed were increased to 10 rem/hr in experimental areas. New shielding at the truck entrance doors was added and additional shielding outside the experimental areas will be added to provide additional protection addressing ALARA levels at the facility boundary. These changes allow ATLAS to deliver ^{7}Li beams at 5 times higher intensity than in the past for in-flight radioactive beam production.

The replacement of the corona voltage distribution system in the tandem injector and other upgrades of tandem system was undertaken this year. This project replaces a nearly-25-year-old system that had deteriorated to the point that the tandem was nearly unusable as an injector. Initial voltage testing began in mid-September. First results are very encouraging, but some additional work is necessary on the charging system and terminal control system. First experiments using the tandem are planned by the end of calendar 2003.

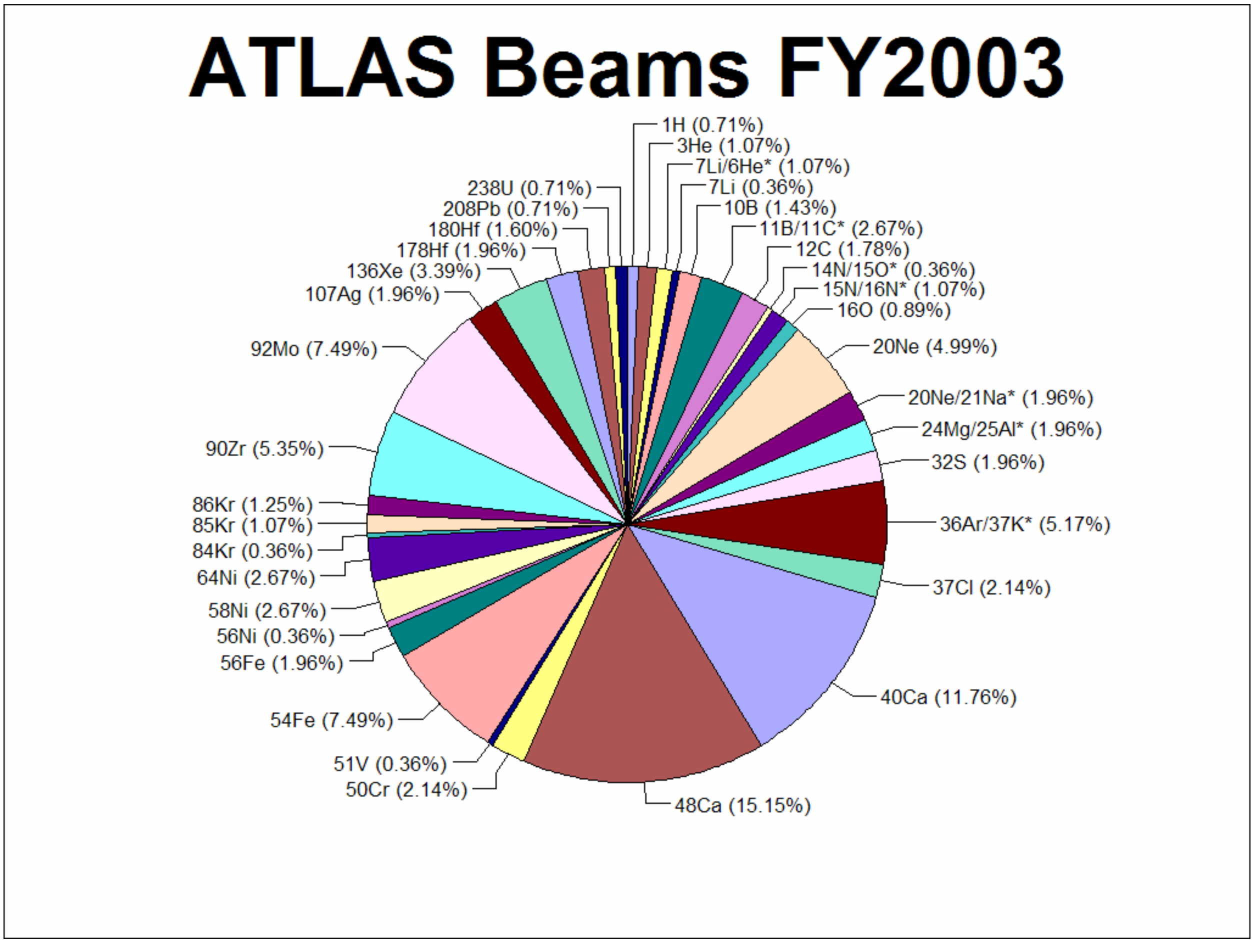

Fig. II-1. Distribution of beam time by isotope provided by ATLAS in FY2003. A total of 36 different isotopes were provided to the research program. Radioactive beams comprised 14.3% of all beam time in FY2003.

B. DEVELOPMENTS RELATED TO ATLAS

b.1. Status of the ECR Ion Sources (R. C. Vondrasek and R. H. Scott)

The ECR ion sources provided 28 different isotopes for the experimental program during the year 2003, accounting for 86% of the beams produced at ATLAS. This amounted to a total running time of 260 days with an availability factor of 0.995. The steady improvement in source availability is attributed to the previously made improvements in the vacuum system as well as continued work in improving the magnetic geometries which generate the plasma confinement field (the magnetic bottle).

As was reported last year, the original ECR2 hexapole was scheduled to be replaced with one constructed of a higher-grade permanent magnet material and with a slightly different geometry. The new hexapole was installed in July 2003 with an improvement in wall field of 9.6%. At the same time the solenoid iron was modified resulting in an increased peak magnetic field on axis. These changes returned ECR2 to a stable operating condition with improved beam currents.

Beam intensity tests were performed before and after the hexapole upgrade with krypton, lead and uranium -- benchmark beams for the RIA driver linac. The results are summarized in Figures II-2 and II-3 below. The achieved intensities represent a factor of 2→4 improvement over the previous best results with ECR2 and rival or exceed the best reported intensities from any ECR ion source.

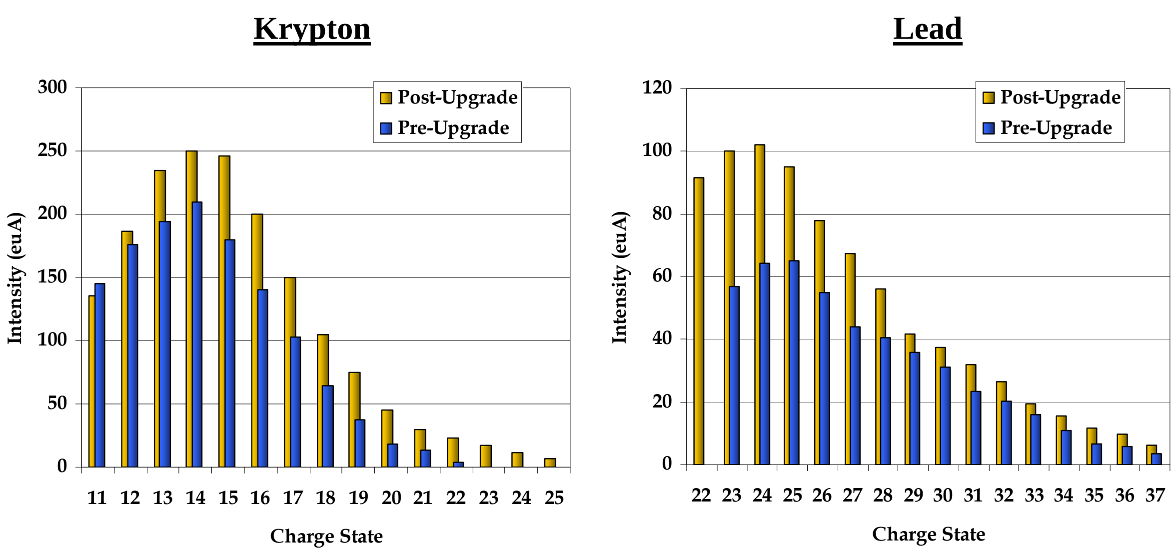

Fig. II-2. The performance of ECR2 for krypton and lead before and after the upgrade of the hexapole magnet using higher performance material.

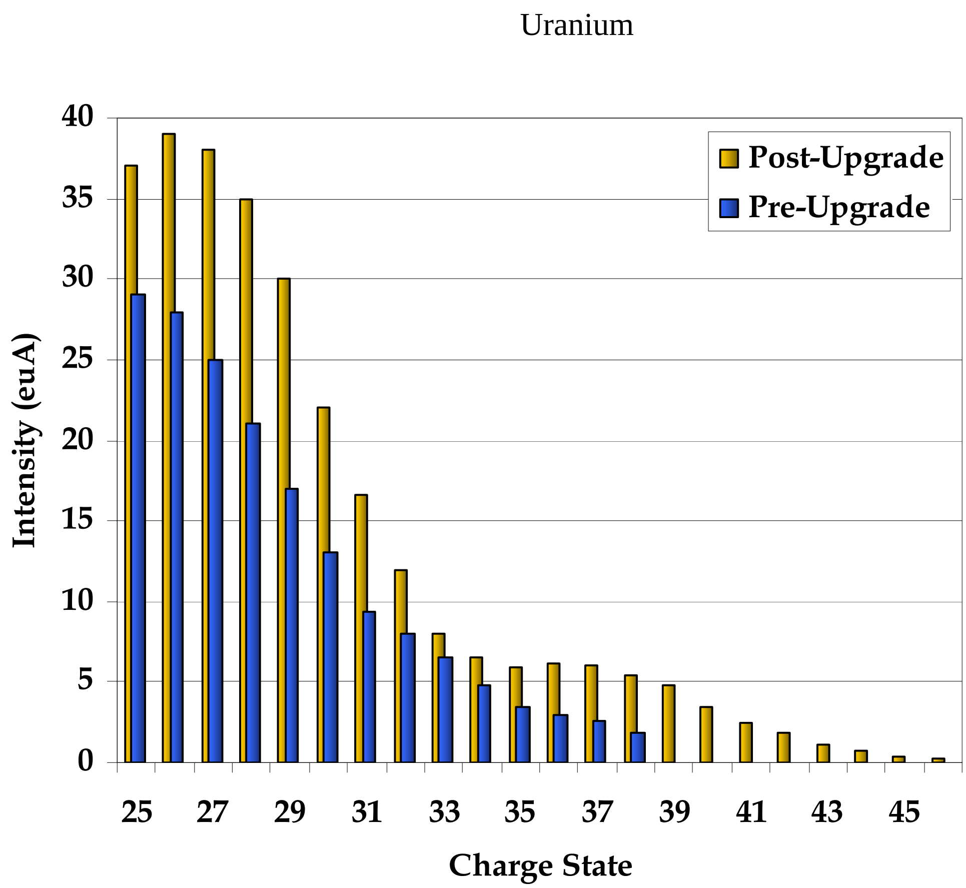

Fig. II-3. The performance of ECR2 for uranium before and after the upgrade of the hexapole magnet using higher performance material.

The cooling of the hexapole continues to be an issue however. This has prompted a new design to be adopted for the hexapole chamber which will provide an increase in cooling capacity as well as directing the water along the pole tips rather than along the sides of the magnets. The new chamber will be fabricated and installed in 2004. Other changes made in conjunction with the new chamber will be an increase in the number of radial ports available for solid material introduction and improved pumping to the central region of the plasma chamber.

A 14-GHz transmitter was purchased this year for later implementation on ECR1. This will enable ECR1 to operate in two-frequency mode and provide a full overlap between ECR1 and ECR2 beam production capability.

b.2. ATLAS ECR Source High-voltage Monitoring and Control (J. M. Bogaty)

When reconfiguring the accelerator to a previously-used tune condition, or scaling from a previous run condition, one of the most difficult parameters to reset exactly is the high-voltage bias of the ion source and the high-voltage platform on which the sources are mounted. Temperature dependence of the resistors in the voltage monitoring system is one example of day-to-day fluctuations that makes repeating previous values to an accuracy of 1 part in 10^4 difficult. A new high-precision voltage divider stack was added to the ECR sources to monitor the extraction voltage more precisely. These devices are now in routine use and have already demonstrated their usefulness in repeatably setting voltages. Similar high-precision voltage divider stacks are being developed for the high-voltage platforms as well and will be installed in FY2004.

b.3. Superconducting Resonator Used as a Beam Phase Detector (S. I. Sharamentov, R. C. Pardo, P. N. Ostroumov, B. E. Clifft, G. P. Zinkann, D. Quock)

The first five RF control modules in the PII section were modified for using superconducting resonators in the first PII cryostat as beam induced phase pick-up. In addition, a software resonator auto-scan package, incorporated into the ATLAS control system was finally developed and tested. These modifications allow using the SCR beam phase detection method routinely.

b.4. Special Test Equipment for Superconducting Resonators (S. I. Sharamentov)

Special superconducting resonators, test equipment including a frequency deviation monitor for 6-400-MHz frequency range, phase-lock loop controller chassis for 48-170-MHz frequency range and RF feedback controller chassis for RIA 350-MHz resonators were designed and built. The equipment allows precise measurements of miscellaneous super conducting resonator RF parameters in both cold and warm conditions.

b.4.a. Frequency deviation monitor

(Figs. II-4 and II-5) can be used for study of the SCR mechanical oscillations (so-called *microphonics*), as well as frequency stability of any RF signal in frequency range of 6-400 MHz. For example, it was used for measuring PII resonators microphonics and frequency stability of the ATLAS Master Oscillator System, with resolution better than 50 mHz .

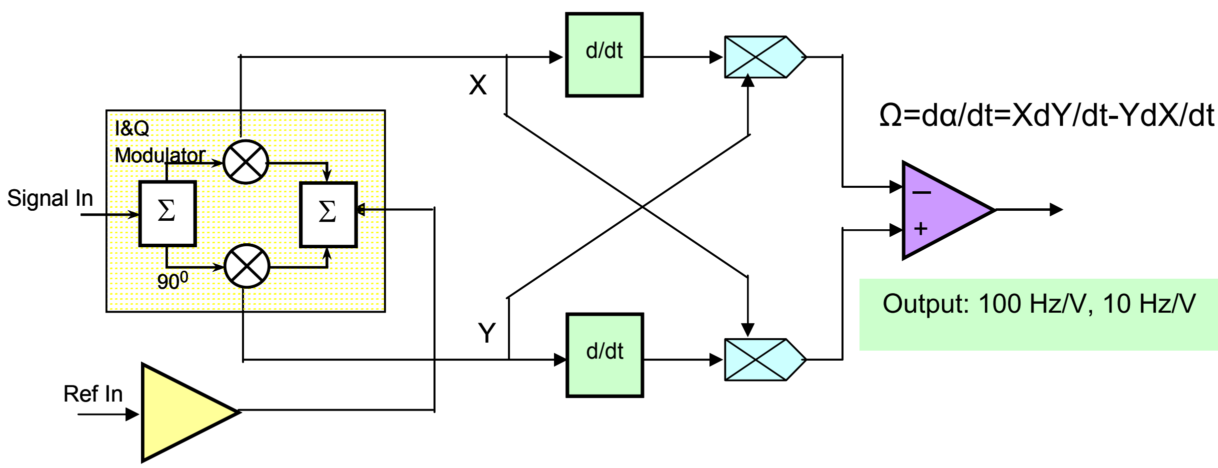

Fig. II-4. Frequency deviation monitor block diagram

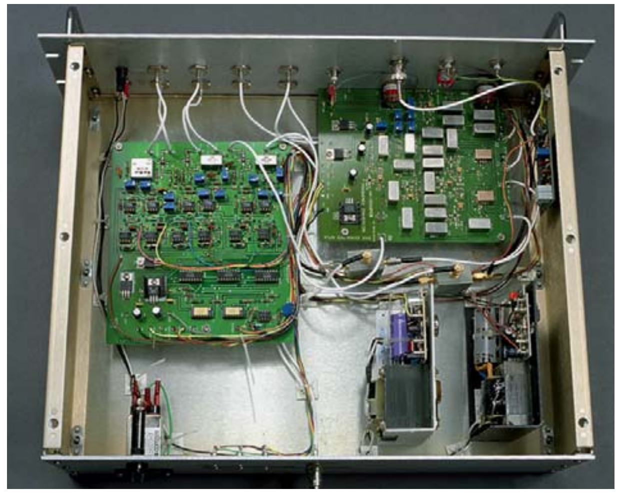

Fig. II-5. Frequency deviation monitor front panel and top view.

b.4.b. RF phase-lock loop controller

(Fig. II-6) chassis is an integrated RF chassis which has all necessary built-in modules for performing precise RF measurements of the SCR both in phase-locked feedback loop and self-exited loop. The chassis consists of a 65 dB gain low-noise preamplifier, limiter, phase shifter section with 48, 72, 97, 109 and 169 MHz phase shifters, 400 degrees range each, voltage-controlled crystal oscillator for the same set of frequencies, one watt broadband power amplifier, phase detector and proportional-integrational feedback controller.

- **Test frequencies – 48, 72, 97, 109, 169 MHz, or external generator**
- **Output power - 1 W**
- **Preamplifier gain – 65 dB**
- **PLL regulation – proportional, integral**

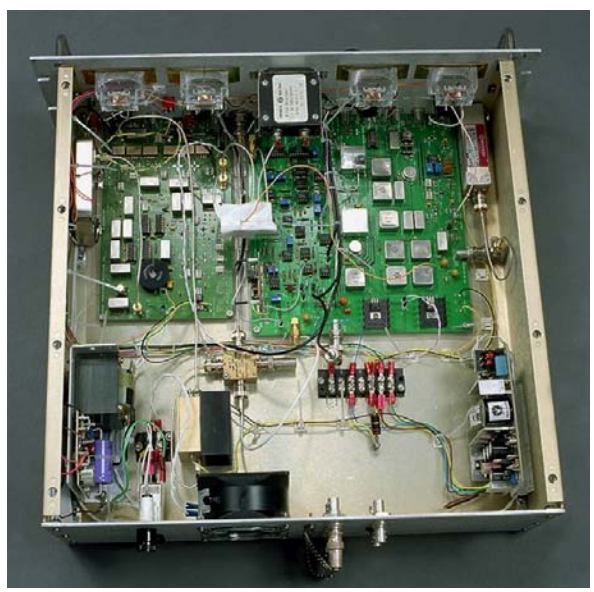

Fig. II-6. RF Phase-lock loop controller chassis

b.4.c. RF feedback controller

Chassis for RIA 350 MHz resonator (Fig. II-7) is a RF control module for controlling both amplitude and phase of the RIA prototype SCR in self-exited loop. It was used for phase and amplitude locking of the RIA single-spoke cavity at 9-MV/m field level.

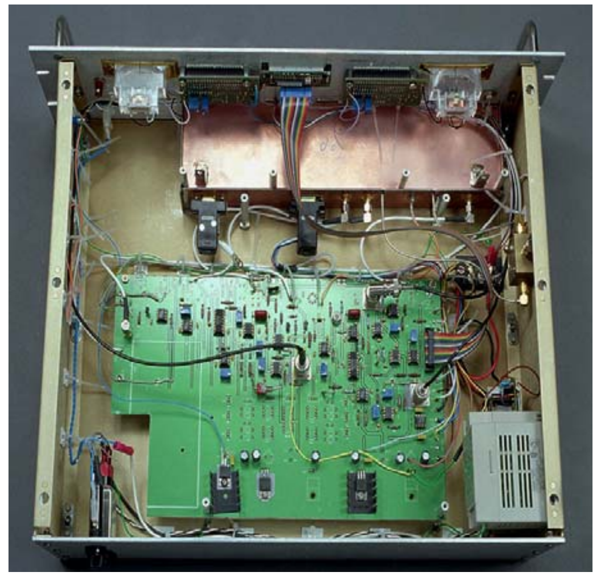

Fig. II-7. RF feedback controller chassis for RIA 350 MHz resonators

b.5 Tandem Upgrade Project (D. Phillips, A. Ruthenberg, P. Strickhorn, D. Quock, F. Munson)

A major tandem repair project was undertaken in summer 2003. The project was driven by the significant deterioration of the voltage grading system for the tandem. The system in use was installed in 1978 as part of a complete refurbishment of the original High Voltage Engineering Corporation (HVEC) FN tandem accelerator. At that time the HVEC resistor voltage divider system was replaced with a separated corona discharge system from National Electrostatics Corporation(NEC). That system has been refurbished twice over the past 24 years, but finally the overall deterioration of the system made replacement necessary.

That corona system was replaced with a resistor-graded system from NEC Corporation. All corona tubes were removed and replaced with two strings of resistors to control the tandem gradient. Two strings of resistors where needed because of the mismatch between the HVEC column and the NEC accelerator tube.

During this same time the opportunity was taken to improve other aspects of the tandem. The old tape reader foil changer was replaced with a new absolute encoder system and a Group 3 communication system. The new control link allowed control of a terminal quadrupole triplet lens and electrostatic steerers to be restored. In addition, the existing terminal ion pump was replaced with a new unit.

b.5.a. Terminal Control

The new tandem terminal control system replaces a system that was installed in the early 1980's. The original system was based on a "stand-alone" design that utilized two single board computers (SBC). One SBC was located in the Tandem's high voltage terminal while a companion system was located at ground potential in the main control room. The two SBCs communicated with each other through fiber optic links that provide the high voltage isolation.

Unlike the original system, the new system was integrated into the CAMAC subsystem of the main ATLAS control system. Group3 Technology Ltd. manufactured the two primary communication components of the new system. The first component is a Group3 "Loop Controller" CAMAC module that resides in a CAMAC crate at ground potential. This device communicates via fiber optic links to the second component, a Group3 "DI" (Device Interface), located in the high voltage terminal. In addition to providing the necessary communications with its ground potential counterpart, the DI provides both analog and digital input/output (I/O) capabilities.

Utilizing the I/O features of the DI, the new system provides control and monitoring of terminal stripping foil positions, as well as control and monitoring of a terminal electrostatic quadrupole triplet. This triplet provides both beam focusing and steering capabilities. Since the new system was integrated into ATLAS's main control system, electrostatic quadrupole settings are archived as part of the accelerator's tune configuration. In addition, the new design presents an opportunity for employing a database that provides stripping foil usage and lifetime data. Possible fields for any particular stripping foil in such a database will include foil thickness, installation and last used dates, as well as a running total of hours the foil was used.

b.6 **ATLAS Control System** (F. H. Munson, D. Quock, and R. Carrier)

The ATLAS control system continues to be based on the commercial product Vsystem, which is marketed by Vista Control Systems. This product provides a real-time database environment, a library of callable database access functions, and a variety of database access utilities. It is necessary to keep the versions of various software packages associated with the ATLAS control system at the most current levels. Since off-line testing of the most recent version of Vsystem was completed, the on-line installation of Vsystem version 4.3 was completed successfully.

The entire internal ATLAS LAN infrastructure was upgraded. The ATLAS Ethernet subsystem was a hybrid network that included 10 Mb coaxial cables (Thinnet) and 10 Mb twisted pair cables (10 Base-T). New cabling and Ethernet switches were installed creating a homogeneous 100 Mb Ethernet network.

The ATLAS control system group maintains two separate domains. Each domain is configured with a Primary Domain Controller and Backup Domain Controller. The hardware components of these systems were upgraded to the latest Intel technology, and the operating systems were upgraded from MS Win NT Server to MS Win 2000 Server technology.

Previously, the control system group constructed and maintained an intranet WEB site on the isolated internal ATLAS control system Local Area Network (LAN). A WEB site was established outside the ATLAS LAN. This was accomplished by splitting the WEB site, placing less-sensitive information on the new more accessible site, and leaving more sensitive information on the internal isolated site. Transparent to users on the internal ATLAS control system LAN, there is access to the external WEB site through the use of a Network Address Translation system.

Communication with accelerator components is currently accomplished with a CAMAC serial highway subsystem. The serial highway topology has certain disadvantages. One solution is PC-based distributed CAMAC I/O processing. To demonstrate the feasibility, a project was completed that provides a stand-alone cryogenic vacuum gauge monitoring system. This is the first practical demonstration at ATLAS of running Vsystem on a PC-based platform running the Linux operating system.

Software projects completed include a new version of the resonator auto-scanning program. The auto-scanning process is typically used to determine the maximum energy gain of any one resonator by measuring the resonator's exit energy at a surface barrier detector. Due to a variety of reasons certain resonators in the PII (Positive Ion Injector) could not be auto-scanned using this method. Based on existing auto-scanning algorithms, but unlike previous approaches, this new process uses special electronics, and provides the capability for determining maximum energy gains with a beam induced RF signal in a secondary downstream resonator.

b.7. ATLAS Cryogenic System (J. R. Specht, S. W. MacDonald, and R. C. Jenkins)

The current method of controlling dewar levels involves increasing dewar pressure along with refrigerator capacity which results in a substantial increase in power consumption. Methods were developed to maintain dewar levels by more effectively controlling the distribution of helium which reduces the amount of excess capacity required for control. There are plans to upgrade the dewar level control system to enable more precise control. This should further reduce the total power consumption of the cryogenic system by eliminating the need to run the refrigerators with excess capacity.

The integration of the use of the out-of-lock strip chart with cryogenic operations was implemented to better understand the effect that the cryogenic system has on the accelerator. This lead to the discovery and correction of many cryogenic operating modes that were disruptive to the operation of ATLAS.

Two additional He compressors were added to the existing ATLAS compressor system. These units were obtained from LLNL. They will provide standby capability in the event of failure of any of our eight previously-installed compressors. In addition they will provide the additional capacity needed when the LLNL 2800 is installed.

b.8. ATLAS Energy Upgrade

An ATLAS energy ugrade is in progress funded as an Accelerator Improvement Project. The project comprises replacing the last cryomodule of ATLAS with a new type based on concepts developed for RIA. Fabrication of the new cryomodule was begun during 2003. A progress report on this project is given in section III. a.8 of this document.