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ANTARES: A STATUS REPORT*

by

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ABSTRACT

Antares is the Los Alamos Scientific Laboratory 100-kJ CO_2 laser driver for inertial confinement fusion experiments. The status of the various Antares subsystems is discussed. These subsystems consist of facilities, front end, energy storage, power amplifier, target, optical alignment and diagnostics, large optics, and controls. The installation of Antares is underway and the schedule to permit experiments which may lead to breakeven in 1984 is discussed.

Introduction

Antares is a large-scale CO_2 laser driver being constructed for scientific breakeven experiments in 1984. This system has been designed as part of the on-going Los Alamos Scientific Laboratory (LASL) CO_2 laser program. It is based on information derived from the original single-beam system built in the early 1970's, the two-beam system which was the prototype for Helios, and Helios, the 10-kJ eight-beam system on which target experiments are now being conducted.

Antares is designed to deliver on target 100-kJ with a 1-ns pulse, and 50-kJ with a 0.25-ns pulse. The design parameters have been described previously.[1] A block diagram (Fig. 1) shows the various constituents of the Antares laser system.

The facilities are the five major buildings in the High Energy Gas Laser Facility (HEGLF) which house the laser subsystems. The front end consists of the oscillator and preamplifiers to generate six pulses to drive the six power amplifiers. The power amplifiers are double-pass, electron-beam-controlled CO_2 lasers to provide the final amplification of the laser pulse. The energy-storage system provides the electrical energy to drive the power amplifier electron gun and the gas sustainer. The target system is housed in the large vacuum beam-tube/target-chamber and focuses the laser beams onto the target pellet. The large optics subsystem includes the salt windows for the power amplifier and the large, single-point diamond-turned (SPDT) metal mirrors and mirror positioners for both the power amplifier and the target system. Optical alignment and diagnostics provides the alignment for the optical system as well as the diagnostics to determine the laser performance. The control system is a hierarchical computer network which controls the entire Antares system.

Facilities

The facilities to house the Antares laser are shown in Fig. 2 which is a model of the entire complex. At the right upper corner is the Laser Hall with beam tubes leading to the target building. The front-end room is located in the Laser Hall basement. Next to the target building is the mechanical building which houses the heating and cooling equipment. This building contains the rotating machinery and is isolated from both the Laser Hall and target building to prevent any unwanted mechanical vibrations disturbing the optical systems. Continuing clockwise, the office building and the warehouse are the remaining structures.

Figure 3 is a photograph of the facilities under construction. All of the buildings have been enclosed. The warehouse is occupied and there is joint occupancy of the Laser Hall by LASL personnel and construction workers. The first power amplifier is under construction. The target building has concrete pads installed for the six turning mirror enclosures and the target chamber. Pittsburgh-Des Moines Steel (PDM) is now installing the vacuum beam-tubes. The completion date for the entire facility is scheduled for March 1980; however, installation of the laser hardware has already begun.

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Front End

The Antares front end generates six annular beams (9-cm i.d. and 15-cm o.d.) for input to the power amplifiers. A pulse is switched out of the oscillator by a series of Pockels cells between crossed polarizers. The pulse is then directed through two series double-discharge preamplifiers, split into six beams and amplified to 90 J per beam by three parallel dual-beam driver modules.

A prototype one-beam system is being assembled in a LASL laboratory. It utilizes an interim oscillator, similar to the Helios oscillator, commercial preamplifiers (Lumonics Model 602 and Model 922), and one half of a dual-beam driver amplifier. The oscillator-preamplifier section has been tested and produced an output of 4 J, which is a factor of 2 above the design requirement. Small-signal-gain measurements are underway on the driver at LASL. The electrical characteristics of the driver were previously determined at the vendor's plant, Systems, Science and Software in Hayward, California. The remaining two driver modules and the second half of the first unit are scheduled to be delivered in 1980. Figure 4 is a photograph of the electron-beam-controlled driver amplifier module installed in a LASL laboratory.

A development program is underway for the final Antares oscillator. This unit is designed to produce 1 MW (1 mJ in 1 ns) and it will be multiline (up to six) with each line separately controlled and selected. Six cw oscillators at the 1-W level will produce the lines.

Power Amplifier

The power amplifier, shown in Fig. 5, has a single, cylindrical, grid-controlled, cold-cathode electron gun surrounded by 12 large-aperture CO_2 electron-beam-sustained discharge sectors.[2] Each power amplifier is designed to deliver 18 kJ and the six modules will provide the 100 kJ required for delivery to the target. A full-scale prototype of one axial section of the power amplifier was built and tested to confirm the basic Antares design with regard to mechanical, electrical, and optical parameters.[3,4] This prototype program was successfully completed and the unit has been available to test actual Antares components under realistic operating conditions.

The annular beam from the front end (<100 J) enters the power amplifier where it is split into 12 separate beams. Each of these is amplified during the two passes through the four discharge regions where approximately 60% of the stored energy is extracted in 1 ns. The discharge chambers are operated at 1800 torr with a 1:4::N_2:CO_2 laser gas mixture.

The electron gun has been delivered to LASL and is being assembled for a separate test program to characterize its performance before it is installed in the power amplifier. Electron-beam uniformity, gun current, shot-to-shot repeatability, and other parameters will be measured. A separate facility for this testing has been completed. This electron-gun testing will start in November 1979 and is scheduled to be complete in May 1980.

Two complete power amplifier outer shells have been fabricated. One, the optical test bed, is being assembled for a full-scale installation and test of optical and optical-alignment components. The second will house the discharge chambers and the electron gun which make up the first power amplifier. A complete electrical checkout of the amplifier is scheduled for the summer of 1980. The pumping chambers and support stands have been delivered and installation has started. Once the separate electrical and optical checkouts have been completed the first power amplifier is scheduled to provide a beam to the target chamber in early 1982. This is the first beamline milestone.

Target System

The Antares target system consists of six, 1.8-m-diameter vacuum beam-tubes, six turning chambers, a target chamber, a target space frame to hold the turning and focusing mirrors, and the target positioner. The target building with its 1.8-m-thick concrete walls and 1.5-m-thick roof has been completed and the turning chamber base plates have been installed on their 3.6-m-thick concrete footings. Installation of the beam tubes has begun and the target vacuum system is scheduled to be completed in May 1980. The target space frame is now being designed and is estimated to be fabricated and installed by June 1980. The target positioner design is based on the successful Helios operational experience. A prototype will be installed in the spaceframe for beamline No. 1 tests, after which it will be retrofitted to final configuration for full six-beam operation.

Energy Storage

Each power amplifier electron gun is driven by a 70-kJ Marx generator (600 kV, 40 kA). A prototype of this gun pulser has been assembled for the initial electron-gun test in the separate facility.

A total of 5.4 MJ is required for the gas discharge of the Antares power amplifiers. Each annular section of a power amplifier is energized by a single 300-kJ Marx generator which delivers more than 200 kA at 550 kV. A total of 24 Marx generators with an energy storage of 7.2 MJ are being fabricated for the complete Antares system to provide an adequate energy margin. A 300-kJ Marx generator was built and tested at LASL.[5] This unit was built to test components such as spark gaps and resistors, as well as system jitter and prefire rate. The Antares Marx generators were submitted to industry for bid. Maxwell Laboratories, Inc. has completed fabrication of the Antares prototype Marx generator (Fig. 6). Evaluation and acceptance testing of this unit is in progress. The four Marx generators required for the first power amplifier test are scheduled for delivery in March 1980.

Large Optics

The large optics for Antares consist of salt (NaCl) windows manufactured by Harshaw Chemical Co., large metal mirrors which are diamond turned at Union Carbide Corporation's Y-12 Plant in Oak Ridge, TN, and precision, motor-driven, mirror positioners.

The 45-cm-diameter, 8-cm-thick NaCl windows are the result of an extensive development program at Harshaw. Antares requires 72 of these windows with each power amplifier utilizing 12. The production facilities have been completed and 28 window blanks have been forged. A prototype 45-cm-diameter window has been completed and evaluated. The window frames which are used as shipping containers have been designed. The first Antares windows will be delivered in February 1980.

The SPDT mirrors utilize a 1-mm-thick copper coating plated on 5-cm-thick aluminum substrates. Prototype mirrors have been measured; a surface finish of 2 μin. peak-to-valley and a figure of less than one wave in the visible have been achieved. Substrates have been fabricated and the Antares production is underway. Over 400 of these large (43-cm x 33-cm) trapezoidal-shaped mirrors are required for Antares. The diamond-turning technology provides a cost-effective method of achieving an optical finish on non-circular mirrors.

Prototype mirror positioners have been completed and are being evaluated. These positioners provide 3.5-μradian-per-step resolution over approximately a 1-degree range with good linearity. Initial measurements show repeatability of better than 1 μradian over the full range of 1 degree. Again, approximately 400 of these positioners are required for Antares.

Alignment and Diagnostics

The alignment system provides an automatic control of the beam from the front end to the target.[6] A number of mirrors are motor-controlled to direct the beam through the system. A complete Antares sector beam line is being installed in the Optical Evaluation Laboratory at LASL to evaluate the performance of two versions of alignment systems. The first, the "see-through" system, utilizes an optical telescope and lights at the mirror centers. The second is a flip-in system using thermopower detectors. The actual Antares mirrors, mirror positioners, and alignment hardware will be used in this evaluation.

The diagnostic system monitors the performance of the laser. Calorimeters and power meters measure the energy at the front end. Additional calorimeters are used to measure the energy entering the power amplifier from the front end and each of the 12 beam sectors at the input to the amplifying region. The double reflection from the wedged output salt windows is directed to a large (0.5 m) surface absorbing calorimeter and power meter in the turning chamber to measure the total output of the power amplifier. A box calorimeter is designed to measure the output into the target chamber. Also, a diagnostic spool is being fabricated which will contain a volume disc calorimeter, power meters and beam quality measuring devices to measure the full power output beam characteristics of each power amplifier before it is connected to the beam tube. Prototypes of these calorimeters are being fabricated for testing and calibration.

Control System

The Antares control system,[7] shown in Fig. 7, is a four-level hierarchical network of 11 minicomputers and approximately 150 microcomputers. The top-level computer, the Integrated Control Center (ICC), provides the integrated control of the entire Antares system. Only one of these units is required. The second-level computer, Subsystem Control Center (SCC), provides individual control of each major Antares subsystem, such as the front end. Four of these units are utilized. The third-level computer, Beam-Line Controller (BLC), controls the beam lines in the Laser Hall. There is one computer per beamline for a total of six. The fourth-level computer, Machine Interface Processor (MI), provides the interface with the hardware and executes the required control functions. About 150 of these units are located throughout the system, near the hardware they control.

All of the connections between the MI's which are located in a high-level pulsed-electromagnetic environment and the upper-level computers located in remote shielded rooms are via fiber-optic cables to eliminate transient interference.[8]

At the present time, the ICC computer, the SCC computers, 1 of the BLC computers, and approximately 12 of the machine interface microcomputers have been received. LASL engineers are writing programs, debugging programs, and providing simulation of required operating modes using these computers. Also, additional MI's are being installed in the Electron Gun Test Facility for evaluation under typical operating conditions.

Schedule

A summary of the Antares Schedule is shown in Fig. 8. The first power amplifier is being installed in the Laser Hall while the construction is being completed. The entire Antares building complex is scheduled for completion in March 1980. The front end for Beam Line No. 1 will be completed and ready to interface with power amplifier No. 1 in November 1980. The first four gas pulsers and first gun pulser will be installed and checked out in June 1980. Power amplifier No. 1 is scheduled to be completely checked out in the Laser Hall by May 1981. The major milestone, Beam Line No. 1 into the target chamber, will be completed in early 1982. The final completion of the Antares system is scheduled for January 1984.

Acknowledgement

I would like to acknowledge the contributions of my colleagues on the Antares team at the Los Alamos Scientific Laboratory.

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Figure Captions

1. Antares block diagram.

2. Antares facilities model.

3. Antares facilities under construction.

4. Front-end driver amplifier.

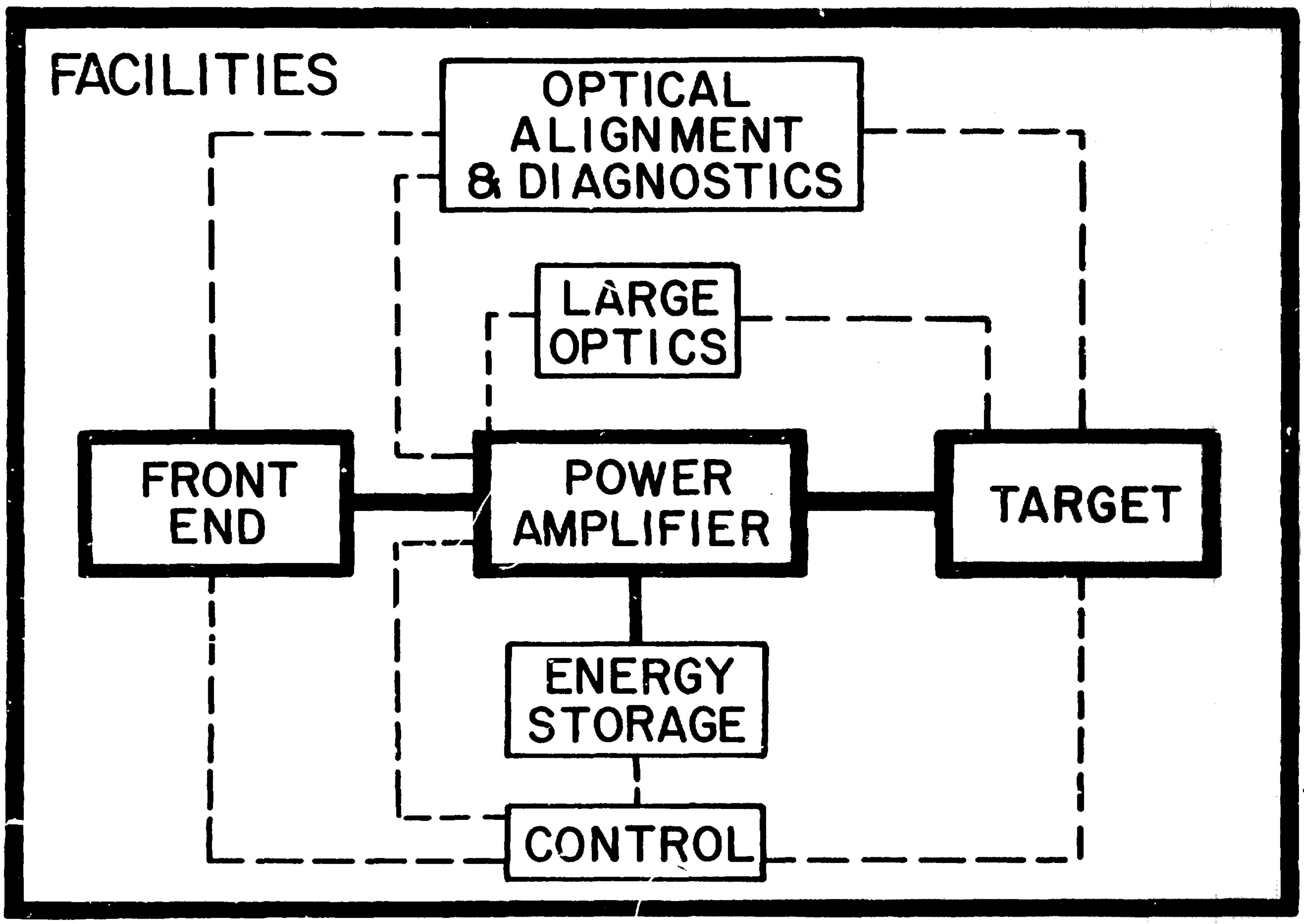
5. Antares power amplifier.

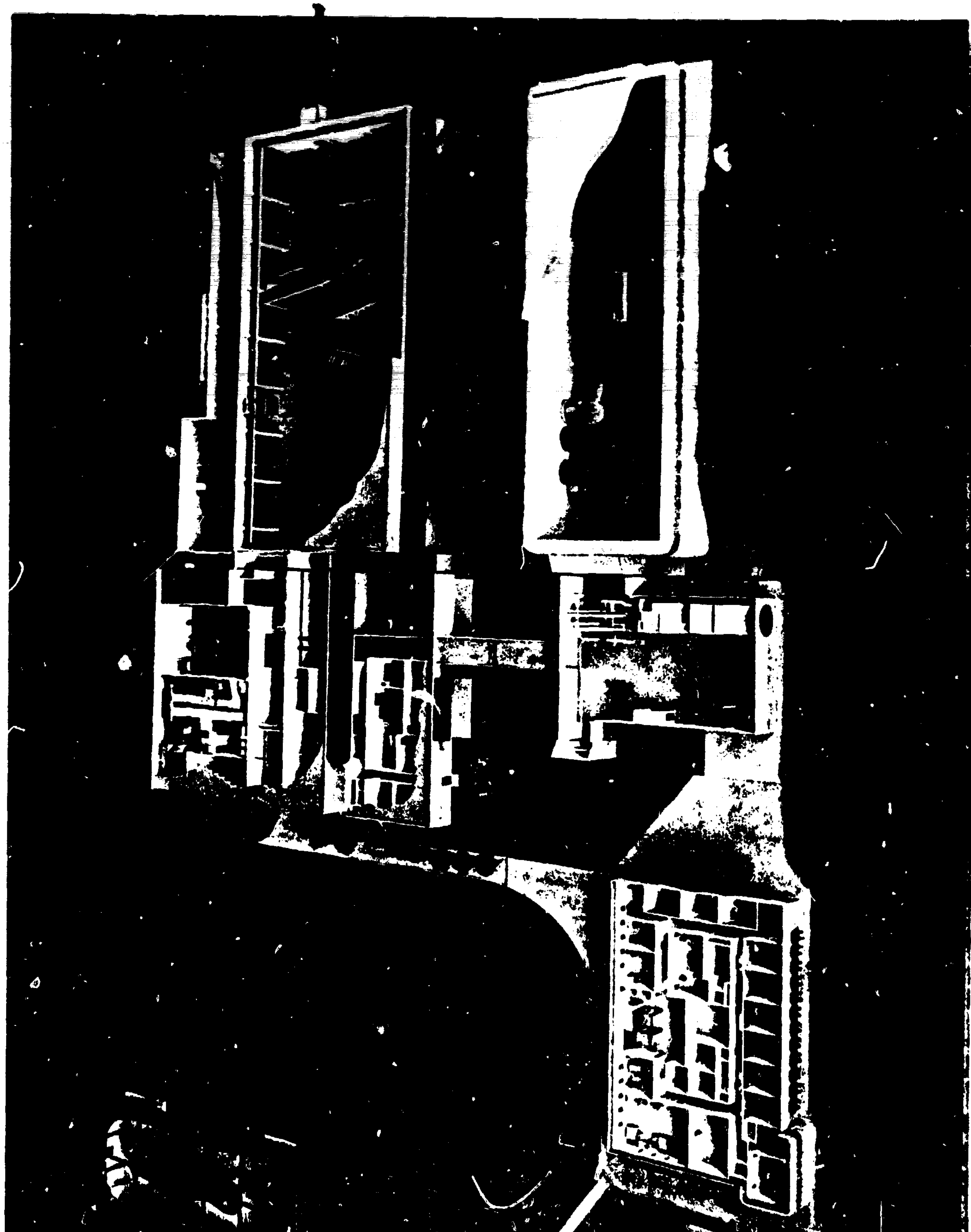
6. Prototype Antares Marx module.

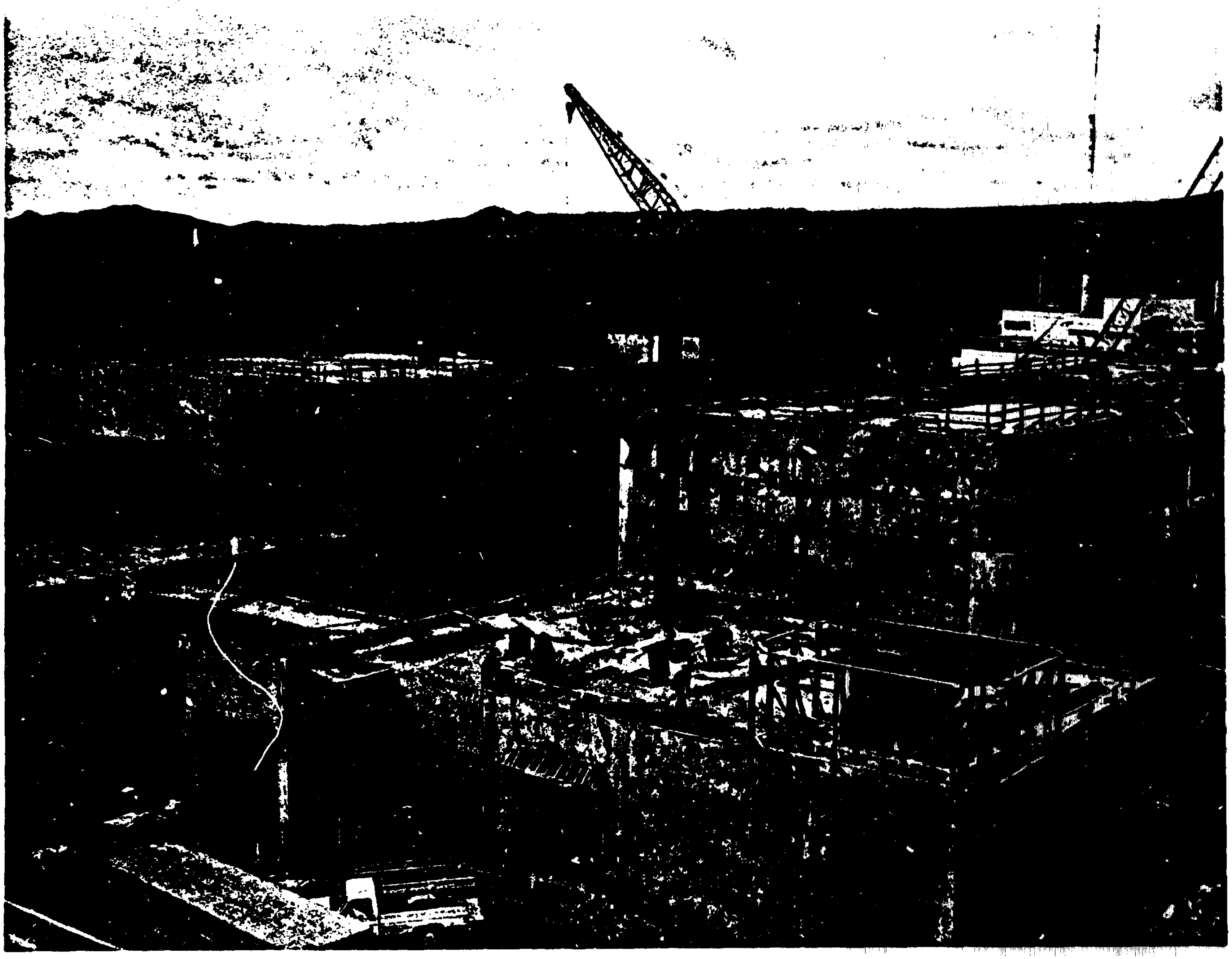
7. Control system block diagram.

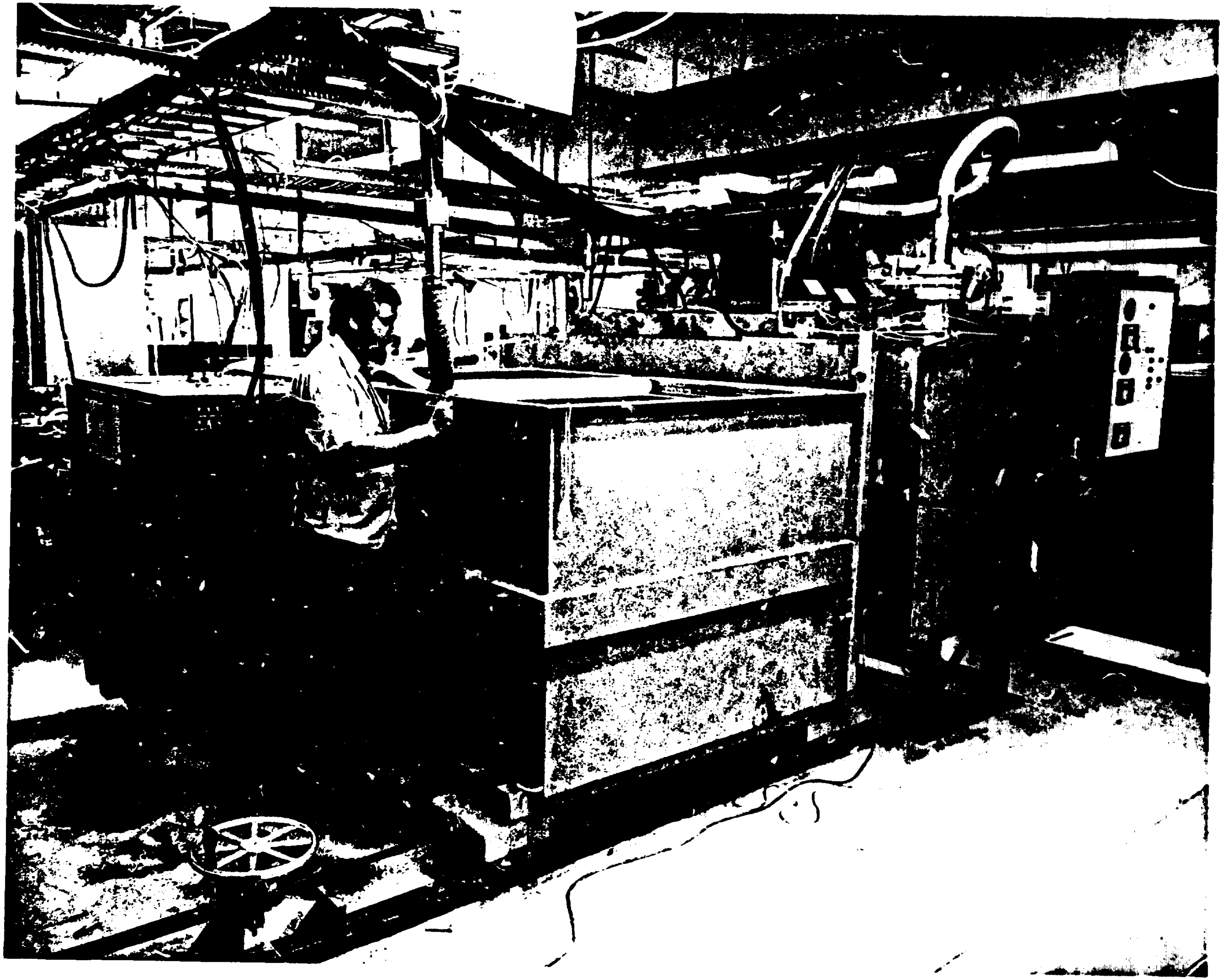
8. Antares summary schedule.

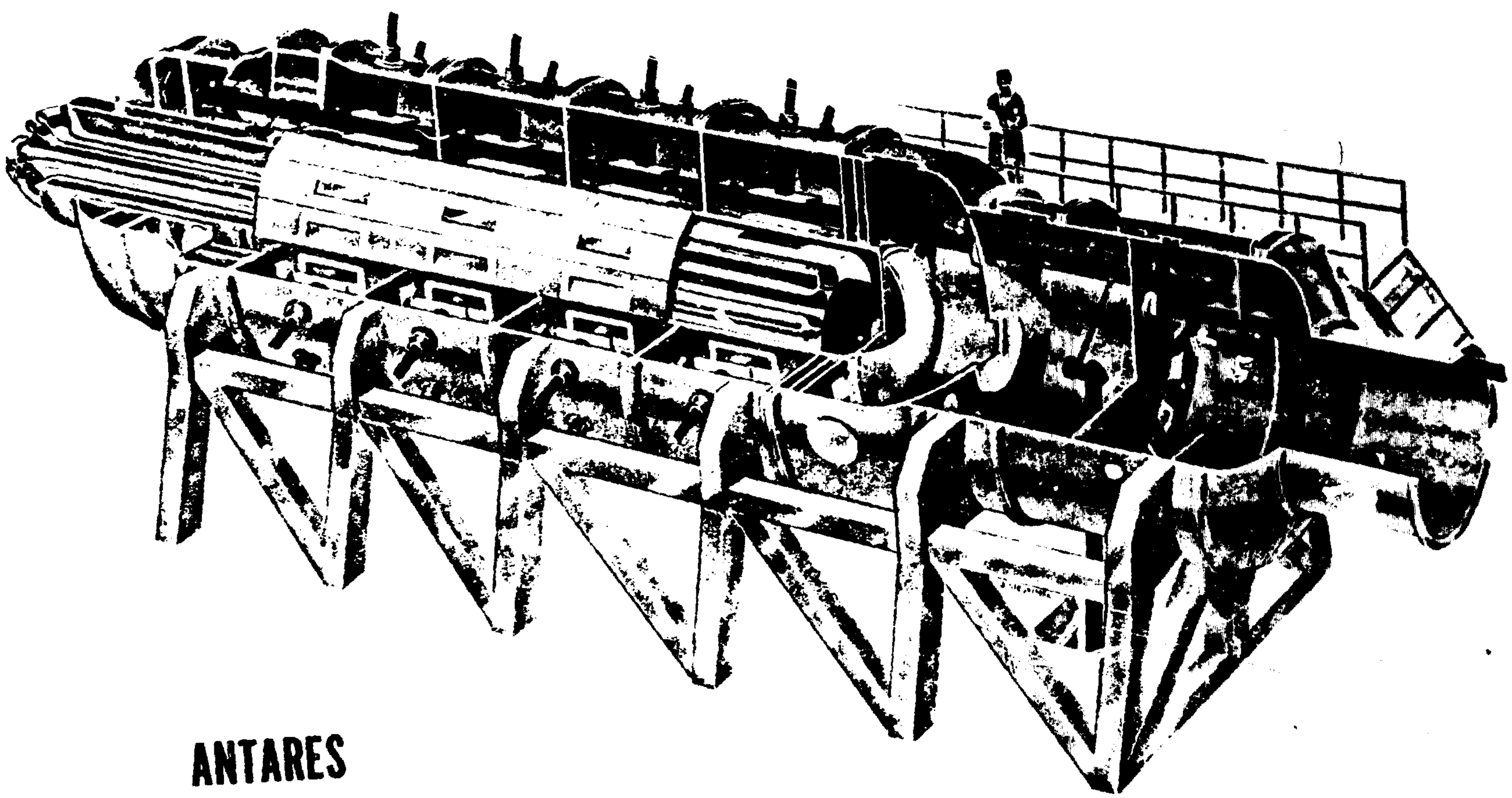
ANTARES LASER SUBSYSTEMS











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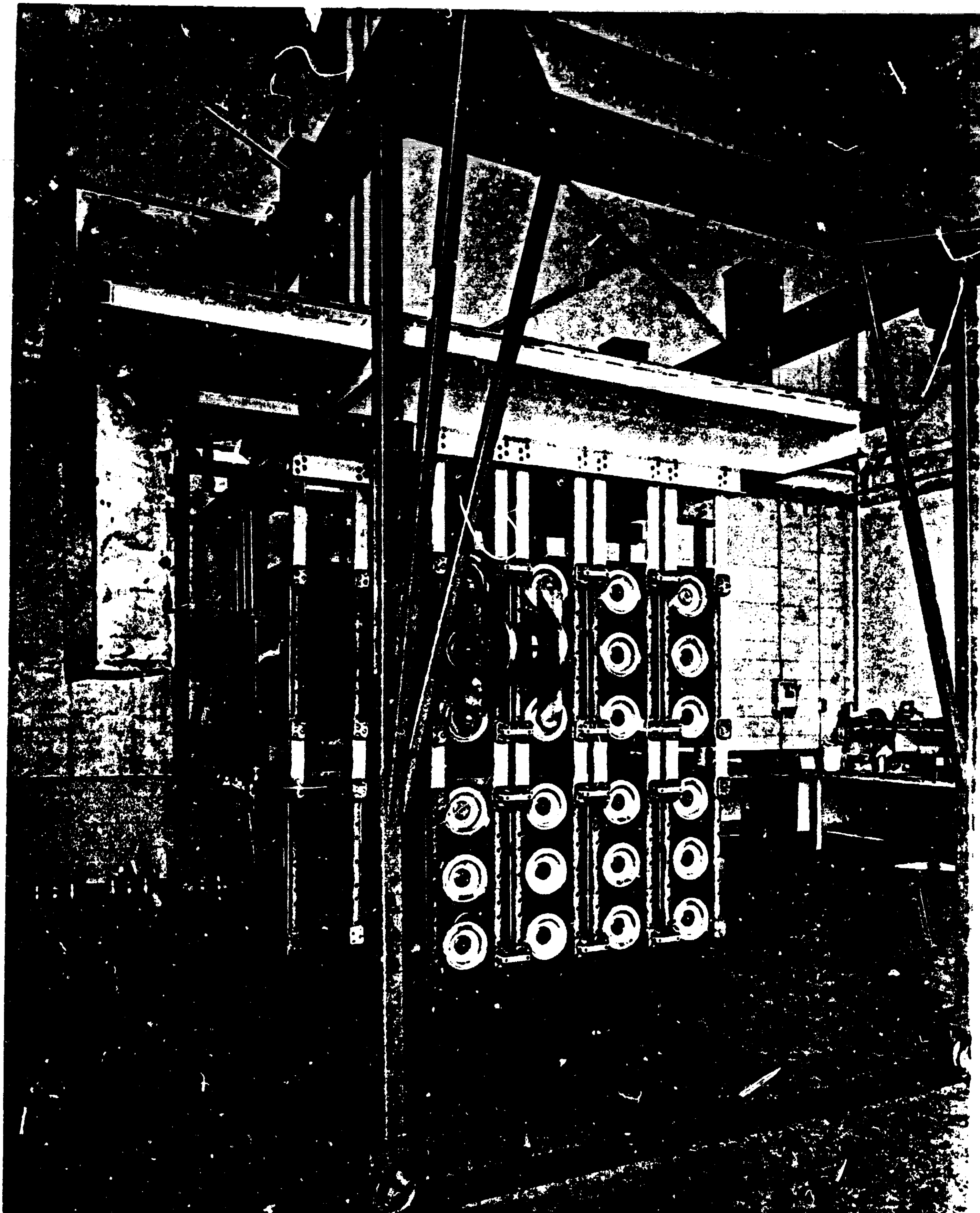

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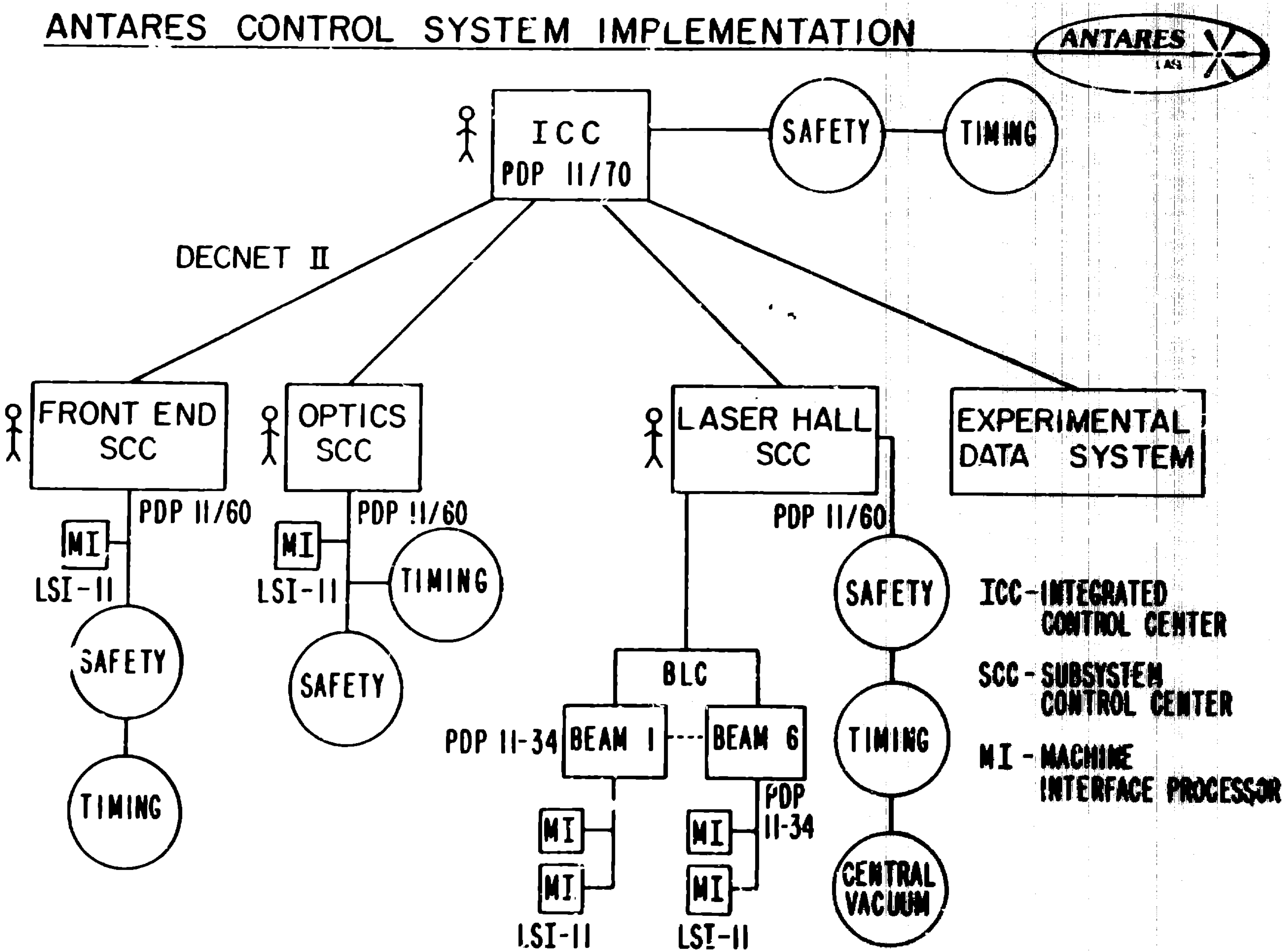

SUMMARY SCHEDULE
ANTARES CRITICAL PATH ELEMENTS

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