Overview
HCAL-J is a hadron calorimeter optimized for the detection of 1 to 10 GeV/c neutrons and protons. Its modular construction will allow it to be relocated to various positions within Hall A using the Hall A overhead crane. Its geometric acceptance will be suitable for use with the SuperBigbite spectrometer.

Function
The detector will be located behind the SuperBigbite spectrometer and provide energy, timing, and position information as specified below.

Performance Requirements
The design criteria are determined by the requirements of the GEp, GMn, and GEn experiments. They are summarized as follows:

Size
The detector will have an active area of 180 cm x 360 cm to match the acceptance of the SBS.

Energy Resolution
The module design has been optimized to allow the use of a high-threshold trigger to reject background events while maintaining high trigger efficiency for the real events. The goal will be to achieve efficiency greater than 95% with a trigger threshold set at 25% of the average signal.

Time Resolution
Simulations show that an rms time resolution of 1.0 ns from the HCAL detector, would result in a trigger efficiency of 80% for the GEn experiment. This is acceptable as the minimum performance criteria, but the HCAL module geometry, scintillator materials, and waveshifters will be optimized to obtain a time resolution better than 1.0 ns rms with an overall goal of achieving a time resolution closer to 0.5 ns rms.

Angular Resolution
The hadronic showers will typically produce signals in a group of modules and a signal-weighted average of module positions will provide a spatial resolution of approximately 8 cm rms. Thus the desired angular resolution of 5 mrad can be achieved by placing the detector 17 m from the target. This allows tight angular cuts allowing rejection of inelastic background as required for the GMn and GEn experiments.
Calibration
Initial HV adjustments and gain calibration will be performed with cosmic rays. Neutron and proton efficiencies will be calibrated by dedicated tagged neutron/proton runs. Software gain calibration and determination of TDC offsets will be performed in situ as part of the experimental program. In addition, the detector will have an LED/fiber optics pulser system that will allow in-situ monitoring of the PMT gains and facilitate data acquisition testing.

Physical Characteristics
The HCAL-J detector will consist of an array of modules, each with a cross section of approximately 15 cm x 15 cm and a length of approximately 100 cm (active volume). Each module will contain 40 alternating layers of scintillators and steel absorbers. In use, hadronic showers are formed in the iron absorbers and the scintillators sample the energy of the showers. The resulting scintillation light is directed to PMTs using wavelength-shifter/light guides that run down the center of each module.

The custom scintillator material has been produced by FNAL’s scintillator extrusion facility. The scintillator contains PPO dye often used in scintillators, but does not contain the usual POPOP dye. St. Gobain BC-484 will be used for the wavelength shifters. Tests have shown that this material is a good match to the PPO emission spectrum. Each module will be readout by a standard 2 inch PMT. Existing PMTs and bases, removed from Hall A's BigHand neutron detector, will be used.

The 180 cm x 360 cm active area design criteria will be achieved by construction an array of modules 12 wide by 24 high. The individual modules are designed to allow this stacking; internal steel ribs will transfer the load of the upper modules to the lower modules. The modules weigh approximately 270 pounds each and the total 288-module calorimeter will weigh approximately 40 tons. The modules will be grouped into 4 sub-assemblies, each 6 modules high. Each sub-assembly will be designed to facilitate lifting by the Hall A 20-ton crane.

Electronics
The HCAL-J array will require 288 channels of standard PMT HV and 288 signal cables. The signals will be read out with a flash ADC. For experiments requiring optimal time resolution, the signals will be split with an asymmetric passive splitter. One output of each splitter will be read by a flash ADC and the second will be discriminated and fed to a high-resolution TDC. The gain-monitoring system will have its own low-voltage power and will be controlled by JLab’s EPICS slow control system.