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ALME and ASSOCIATES

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6219 Bright Plume
Columbia, MD 21044-3790
Phone: 410-740-1118
FAX: 410-740-1161
e-mail: marvalme@cpcug.org

Final Report

Facilitization of the National Ignition Facility (NIF) for Radiation Sciences Experiments

Dr. John F. Davis

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**CONCEPT DEVELOPMENT OF RADIATION SCIENCES EXPERIMENTS
FOR THE NATIONAL IGNITION FACILITY**

FINAL REPORT OF SUBCONTRACT B324681

by John F. Davis, Alme&Associates

DECEMBER 1995

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CONCEPT DEVELOPMENT OF RADIATION SCIENCES EXPERIMENTS FOR THE NATIONAL IGNITION FACILITY

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I. INTRODUCTION

This report will provide a summary report of work performed under Subcontract B324681 from November 1 through December 14, 1995 and covers work relevant to Subtasks 1-11. The work performed under this contract was presented and reviewed at the NIF Radiation Sciences Users Group meeting held on November 29-30. Present were senior representatives from the NIF Project, the DOE Office of the NIF, the DOE ICF program, and the Defense Nuclear Agency. This report is divided into seven sections, not including the Introduction to include; Potential Test Capability, Operational Scenarios, Facilitization Issues, Security Issues, Performance/Cost/Risk Considerations, a Summary of Requested Modifications to the NIF and finally, Conclusions. Within each section will be a short narrative and a copy of the view graph presentation.

Considerations of the changes to the proposed NIF facility that would be necessary to permit effective nuclear weapons effects testing (NWET) must be based on assumed needs for NWET and a NIF operating plan. The matrix of potential NIF effects tests is presented based on the NRSUG report and from excerpts from the DNA Simulator Roadmap (in Draft). The facility modifications discussed in this report are based on those potential testing needs without regard to the relative priorities of any of the specific experiments.

A detailed NIF operational plan does not yet exist. For the purposes of this discussion, it is assumed that NIF will be capable of three shots per 24-hour day, five to seven days per week, most of which will be laser only or very low yield DT capsule experiments. The number of high gain shots, limited by ES&H considerations, is assumed to be less than 20 per year, and the number of those dedicated to NWET will be determined by competing priorities. It is also assumed that there will be a high demand for the facility, so that it will be necessary to limit the experiment set up and tear down times and to minimize interference with other users. Unless an experimenter is prepared to use a shot every eight hours, it is assumed that it will be necessary for him to remove his experiment and permit another experiment to be installed, aligned and checked out before the next eight-hour shot. Since only eight hours are available for removal of one experiment and installation of another, the facility must permit good pre-alignment and checkout prior to final installation so that experiments can proceed in parallel.

The assumption that the facility will be fully utilized so that it is necessary to severely limit the time of any one experimenter in the test chamber is important since it will significantly impact the facility design for NWET (and probably for other DOE experiments as well). However, even if the facility is not fully subscribed, it is likely to be cost effective to the experimenters to minimize the test chamber access time.

II. POTENTIAL TEST CAPABILITY

Considerations of the changes to the proposed NIF facility that would be necessary to permit effective nuclear weapons effects testing (NWET) must be based on assumed needs for NWET and a NIF operating plan. The matrix of potential NIF effects tests is presented based on the NRSUG report and from excerpts from the DNA Simulator Roadmap (in Draft). Significant effort was expended to encompass the system, subsystems, components and phenomenology testing methodology needs. The goal effects test capability was divided into three x-ray spectral regions, cold, warm and hot. Upon reflection, perhaps four spectral regions would have been more appropriate, cold, cool, warm and hot, with material testing in cold and cool and electronics in warm and hot. The matrix of goal NWET capability is presented in the following three tables.

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - COLD

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Fluence (cal/cm ²)	Area (cm ²)	Spectrum Fidelity	Fluence - Area
Cold 0.1 - 6 keV	Surface Effects	Components e.g., mirrors, baffles, solar cells, thermal control surfaces	0.01 - 5	5-50	High Fidelity Clean	10-250
Cold 0.1 - 6 keV	Performance Degradation, Mechanical Damage	Subsystems, e.g. optical assemblies, solar panels	0.01 - 1	100-3,000	High Clean	100-3,000
Cold 0.1 - 6 keV	Thermal Structural Response	Telescopes, Seekers	0.5-5	1,000-2,000	Medium	500-10,000
Cold 0.1 - 6 keV	Surface Effects & Blowoff	Phenomenology	5-50	5-100	Medium	500-5,000
Cold 0.1 - 6 keV	Blowoff	RVs, Warhead & Safety Verification	5-50	1,000-5,000	Low	5,000-50,000

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - WARM

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Fluence (cal/cm ²)	Area (cm ²)	Spectrum Fidelity	Fluence - Area
Warm 5-30 keV	TSR, Performance Degradation	Subassemblies Telescopes, Pointer tracker	0.1-5	50-300	Medium	30-1,500
Warm 5-30 keV	TSR, Performance Degradation	Subsystems e.g. Optical assemblies	0.1-5	300-3,000	Medium	500-10,000
Warm 5-30 keV	Thermal effects, bond strengths, new materials, etc	Phenomenology, RV Subsystems	5-50	5-400	Medium	500-10,000
Warm 5-30 keV	Mechanical Response	Missile Subsystems	1-10	1,000-8,000	Low	5,000-50,000
Warm 5-30 keV	Thermo-mechanical Shock	RVs, Pen-aids Missile Bodies,	5-50	1,000-5,000	Low	5,000-100,000
Warm 10 - 60 keV	SGEMP	Strategic Systems and cable assemblies	0.01-0.1	3,000-10,000	High	1,000

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - HOT

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Dose kRads(Si)	Dose Rate kRads (Si)/sec	Area (cm ²)	Spectrum Fidelity	Dose - Area kRads(Si)-m ²
Hot 30 - 300 keV	Electronics	Components	50-150	5.0×10^{12}	1-100	Medium-High	0.01-0.15
Hot 30 - 300 keV	Electronics	Ensembles	10-50	$2-3 \times 10^{12}$	100-1,000	Medium-High	0.5 - 5
Hot 30 - 300 keV	Electronics	Subsystems & System	10-50	1.0×10^{12}	1,000-10,000	Medium-High	5 - 20

Potential NIF NWET Test Capability

After careful review of the potential laser plasma radiation source test capability to perform nuclear weapon effects testing, several conclusions can be arrived. The laser operating at its design wavelength and power (3ω at 1.8 MJ energy) can produce adequate 1-5 keV photons for cold x-ray weapon effects tests with a potential test capability, expressed in a fluence-area product of approximately 3,800 cal (assuming $\pm 10\%$ uniformity) and thus a potential fluence of 0.1 cal/cm^2 for a test area of $38,000 \text{ cm}^2$. The total x-ray yield including soft x-rays (0.1-5 keV) is potentially 6,300 cal.

The x-ray pulsewidth for these sources (assuming a point source and 12-16 targets) can be varied from approximately 3 ns to greater than 48 ns and the source spectrum will have significant continuum component. One of the basis of the facilitization is therefore to request a test port for NWET with a test area up to $40,000 \text{ cm}^2$.

The expected debris and impulse from these sources should be small enough to allow testing for all but for perhaps the most stringent test scenarios. The debris mass for these sources is expected to be approximately 4 milligrams with a thermal dispersion velocity of about $10 \times 10^6 \text{ cm/sec}$ (mid-Z, 5 keV). For a cold x-ray test with a FxA of 3,800 cal, at 300 cm the fluence is 0.1 cal/cm^2 . At this distance, the impulse is about 35 millitaps and the debris areal mass is 3.5 nanograms/ cm^2 . Assuming that all of the incident mass from the source sticks to the surface (note the bulk of the debris mass will be typically carbon, hydrogen, oxygen and other low Z elements) then this represents $7 \times 10^{13} \text{ atoms/cm}^2$ which should be compared to a monolayer of silicon ($1.6 \times 10^{15} \text{ atoms/cm}^2$). For tests at 1.0 cal/cm^2 , these debris numbers should scale accordingly ($\sqrt{10}$ times) and thus may also be acceptable at this higher fluence.

With ignition, the potential cold x-ray source strength will increase approximately a factor of about six (6) over a 1-5 keV laser target point source, but the estimated debris will increase a factor of 100 for a 15 MJ baseline capsule case. With ignition sources optimized for effects testing, the increase in test capability can be somewhat higher. Estimates of a 15 MJ yield capsule is that it will be able to test large objects with areas up to $14,000 \text{ cm}^2$, with a cold spectrum fluence on the order of 1 cal/cm^2 , with an impulse of < 10 taps.

Thus, with laser plasma radiation sources combined with the potential with ignition represents a significant, large area test capability that can have meaningful test utility for satellite systems, satellite subsystems, interceptor subsystems, pen-aid small systems and/or components and for missile components. Therefore, with the baseline NIF design, the laser weapon effects test capability, without specifying increased laser energy or 2ω into the target chamber and without the need for increased beam steering and focusing, will have substantial test capability. This large area cold x-ray test will be the driving factor for a minimum NWET facilitization. However, the presence of some significant test capability with the baseline laser design warrants the development of the maximum test capability for weapon effects that can be implemented without significant cost or schedule impact to the NIF project.

Considering the potential warm (5-15 keV) test capability of laser target sources is 1,250 cal with a maximum test fluence of approximately 10 cal/cm^2 . Presently there is a shortfall in test

capability to test TSR in material with appropriate test areas and x-ray spectrum and fluence. The potential test capability with the NIF for warm testing will be 3-4 times that expected for Decade in the PRS mode or expected from PBFA-2Z. However, these potential PRS test capabilities from these sources has not been optimized (or yet demonstrated) and actual test capability may be substantially higher. Nevertheless, the potential NIF warm (5-15 keV) test capability will allow testing of satellite subsystems and interceptor subsystems. With distributed sources, the test area (at same uniformity) can increase approximately a factor of 3.5. This represents overall about an order of magnitude increase in potential test capability in this regime.

Hot electron bremsstrahlung sources may have source parameters that could represent significant improvements over existing test capabilities in both spectral and temporal fidelity. In particular, the ability to vary the pulse shape to attain more threat-like rise and fall times is an important advancement. This would allow electronics tests to achieve the desired peak dose rates without the excessive pulse-widths of existing AGT simulators that tend to overdose critical electronics. This potential test capability also better stimulates realistic railspan collapse, and circuit and cavity ringing.

These sources rely on the conversion of red, 1ω laser light to produce hot electrons, which then impact the containment walls of the source to produce cold target bremsstrahlung x-rays. These x-rays will therefore emit a continuum spectrum with the highest energy x-rays directly a function of the highest energy of the hot electrons. Assuming 3 MJ 1ω laser irradiation of a suitable target, then the overall conversion efficiency to x-rays is approximately 0.25% for a source strength of 7.45 kJ. This translate into a FxA for $\pm 10\%$ uniformity of 55 cal and for $\pm 33\%$ uniformity (no cosine weighting) to approximately 195 cal. The source spectrum is characteristic of approximately a 250 keV endpoint energy bremsstrahlung source and resembles a 15 keV threat spectrum. For a 250 keV endpoint energy bremsstrahlung spectrum (above 15 keV), the conversion factor is roughly 10^6 rads(Si)/cal/cm². Thus, for a 10^4 cm² test object and a 3 ns pulse, the potential test capability for these sources for electronics testing corresponds to a dose on the order of 20×10^3 rads(Si) and a dose-rate of 5×10^{12} rads(Si)/s. Assuming only photons above 30 keV, then the area for the same dose of 20×10^3 rads(Si) is 3,000 cm².

Underdense Sources

The present theoretical understanding of underdense targets implies optimization of the x-ray output in the region of 5-15 keV requires around $5-6.4 \times 10^{15}$ watts/cm² in a density of 1-3 atmospheres ($2.7-8.1 \times 10^{19}$ atoms/cm³) in target volumes around 0.0115 - 0.035 cm³ (2.8 - 4.1 mm diameter). This would imply optimization of conversion efficiency at 3 to 4 beamlets per target (@ 1.8 MJ, 3ω , 3 ns pulsewidth) which is 112.5 - 150 kJ/target. This implies 12 to 16 targets is a reasonable design point for consideration of laser target sources.

If the conversion efficiency of 2ω (green light) is approximately the same as for 3ω , with the nominal available 2ω energy of 2.4 MJ then this would imply 50 kJ/beamlet and thus 2-3 Beamlets per optimized underdense target. This would give 16-24 possible targets. The baseline design for laser steering and pointing is ± 3 cm. For 16 evenly spaced 4 mm diameter, this would imply a target spacing of 16 mm. Possible interaction of x-ray and debris from adjacent sources needs to be investigated to understand limits of spacing and timing. First estimates would imply

that ± 3 cm target area must be increased to around ± 5 cm for optimum equivalent point source laser plasma radiation sources. The use of 12 to 16 targets with a nominal pulsewidth of 3 ns each would imply a possible x-ray output pulsewidth between 3 - 48 ns.

Distributed Sources

Since laser target sources will be made up of many individual sources, this allows the consideration of distributed sources. The promise of distributed sources is to have more uniform illumination at the test object to more accurately represent a plane wave illumination. Or, distributed sources could have larger test areas at fluences and test fluence uniformity comparable to point sources. No analysis of optimization of distributed sources for fluence uniformity and beam pointing/focusing considerations has been made. However, to consider the advantages and potential facility impacts of distributed sources, the preliminary considerations of Larry Suter will be utilized.

For a point source with 80% uniformity (fluence $\pm 10\%$) then the $F \times A \approx 0.019 \times 0.406 \times \phi$ cal; where ϕ is the X-ray source intensity in joules. For a four point distributed source, at a distance of 57% of the point source distance R , one has the same fluence with $3.5 \times$ the area of the point source. Thus, average fluence for 80% uniformity is $f_{pt} = (0.9) / (4 R^2)$ and the same fluence for a distributed source can be at a source to test plane distance d of $0.57R$. For the four point sources, the spacing will then be about $1.7 \times d$ or approximately R . Since for this example, the four sources lie in a plane, and the laser beams are incident from many angles from the target chamber, distributed sources will complicate beam steering and focusing to optimize these sources for maximum utility.

Notes on beam aiming and focusing

There is an issue as to whether beam aiming and focusing to a distributed array of targets can be accomplished without 1ω (and/or 2ω) intersecting the test object. First assume a square distributed source target array with targets at each corner as shown in Figure 1. The test area dimensions is larger than the source dimensions (area about 40% larger or by a characteristic dimension about 20% larger). Further assume that the test object is inserted with its axis coincident with the x-axis of the target chamber and that the target array is orthogonal to the test object (in the y-z plane). Note that there are 48 Beamlets total, thus, this implies with a total of 12 targets there are 4 Beamlets/target, 16 targets - 3 Beamlets/target or 24 targets - 2 Beamlets/target..

Divide the target sphere into 8 sections. The Beamlets are arranged into two cones around the $\pm z$ -axis. Looking from the top, the test object is inserted from the bottom of the page (south) and for the upper hemisphere the SE 1/8 is labeled OCT-A, SW OCT-B, NW OCT-C, NE OCT-D. For the lower hemisphere the SE 1/8 is labeled OCT-E, SW OCT-F, NW OCT-G, NE OCT-H. In each hemisphere of the target chamber, there are 24 beamlets or 6 beamlets in each 1/8 sphere. Whether 12, 16 or 24 target array, the number of Beamlets to $1/4$ of the target array (2, 3 or 4 targets) is just $1/4$ of the total Beamlets or 2 of the 8 Sections.

Laser Plasma Radiation Source Requirements

From considerations of the laser power and energy deposition to produce x-ray sources in the 1-5 keV X-ray spectral region, and consideration of distributed sources using an underdense target - Gasbags, a possible beam targeting and firing sequence can be developed. The beam intensity requirement is approximately 5×10^{14} watts/cm² and the power density requirement is approximately 5×10^{-5} watts/atom. This translates to about 1.35×10^{15} watts/cm³ for a mid-Z gas at standard temperature and pressure. With 3 ns pulsewidth this implies a requirement of about 4 MJ/cm³ deposited into the gasbag. For a 3 ω Beamlet (4 beams) this is 37.5 kJ for a 3 ns laser pulse and implies 1.25×10^{13} watts. For 2 Beamlets/target the energy onto the target is 75 kJ and thus the target volume is 1.875×10^{-2} cm³ corresponding to a target diameter of around 3.3 mm. Two beamlets per target would imply the possibility of 24 targets. Four (4) targets firing in a sequence, 6 firing sequences would give an X-ray pulsewidth around 18 ns with 3 ω . For 2 ω the x-ray pulsewidth in this targeting scenario would be about 24 ns.

From this crude scaling, a laser aiming, focusing & firing sequence requirement can be developed. For 3 ω laser operation, assuming 1.8 MJ to targets in the chamber for a 1-5 keV X-ray source, the required spot size is approximately 1780 microns (this implies spot 54% of 3.3 mm diameter target). For the case of 2 Beamlets / target, this would imply the possible target scenario of 24 targets equally spaced in a circle. For a 50 cm diameter target array, this implies 6.54 cm apart, and for a 100 cm diameter implies 13.09 cm apart. A possible laser firing sequence is shown below.

Firing Sequence:

- At t_0 - 4 equally spaced targets illuminated on first firing sequence
- At $t_0 + 3$ ns, - 4 equally spaced targets illuminated on second firing sequence
- At $t_0 + 6$ ns, - 4 equally spaced targets illuminated on third firing sequence
- At $t_0 + 9$ ns, - 4 equally spaced targets illuminated on fourth firing sequence
- At $t_0 + 12$ ns, - 4 equally spaced targets illuminated on fifth firing sequence
- At $t_0 + 15$ ns, - 4 equally spaced targets illuminated on sixth firing sequence

For the production of 5-15 keV X-ray sources the power and energy deposition requirements to produce efficient sources is approximately an order of magnitude increase over sources emitting between 1-5 keV. From considerations of the laser power and energy deposition to produce x-ray sources in the 5-15 keV X-ray source, and consideration of distributed sources using an underdense target - Gasbags, a possible beam targeting and firing sequence can be developed. The laser beam intensity requirement is approximately 5×10^{15} watts/cm² and the power density requirement is approximately $2-3 \times 10^{-4}$ watts/atom. This translates to about 6.75×10^{15} watts/cm³ for a mid-Z gas at STP.

With a 3 ns pulsewidth this implies an energy density requirement of about 20 MJ/cm³. For a 3 ω Beamlet (4 beams) this is 37.5 kJ and a 3 ns laser pulse implies 1.25×10^{13} watts. For 2 Beamlets/target the energy onto each target is 75 kJ and thus the target volume is 3.75×10^{-3} cm³ and the target diameter around 1.93 mm. This raises the issue of whether or not a 1.93 mm diameter gasbag adequate for 3ns pulsewidth laser irradiation. Two beamlets per target allows for 24 targets and gives the possibility of 4 targets / firing sequence, 6 firing sequences and a

potential X-ray pulsewidth around 18 ns with 3ω and 24 ns for 2ω .

For the case of 3 Beamlets/target the energy per target is 112.5 kJ, which yields a target volume of $5.625 \times 10^{-3} \text{ cm}^3$ and a corresponding target diameter of around 2.2 mm. Three beamlets per target allows for 16 targets and gives the possibility of 4 targets / firing sequence, 4 firing sequences and a potential X-ray pulsewidth around 12 ns for 3ω , 16 ns for 2ω .

From this crude scaling, a laser aiming, focusing & firing sequence requirement can be developed for warm x-ray sources. For 3ω laser operation, assuming 1.8 MJ to targets in the chamber for 5-15 keV X-ray source, the required spot size is approx 565 microns, (this implies spot 25% of 2.2 mm diameter target). For the case of 3 Beamlets / target, this would imply the possible target scenario of 16 targets equally spaced in a circle. For a 50 cm diameter target array, this implies 9.8 cm apart, and for a 100 cm diameter implies 19.6 cm apart. A possible laser firing sequence is shown below.

Firing Sequence:

- At t_0 - 4 equally spaced targets illuminated on first firing sequence
- At $t_0 + 3 \text{ ns}$, - 4 equally spaced targets illuminated on second firing sequence
- At $t_0 + 6 \text{ ns}$, - 4 equally spaced targets illuminated on third firing sequence
- At $t_0 + 9 \text{ ns}$, - 4 equally spaced targets illuminated on fourth firing sequence

The following two tables summarizes the assumed laser parameters and the laser plasma radiation source parameters for efficient x-ray production.

ASSUMED LASER PARAMETERS

Laser Frequency	Laser Energy (MJ)	Pulsewidth (ns)	Energy/Beamlet (kJ)	Power/Beamlet (watts)
3	1.8	3	37.5	1.25×10^{13}
2	2.4	4	50	"
1	3.0	5	62.5	"

LASER PLASMA RADIATION SOURCE PARAMETERS

X-ray Source (keV)	Beam Intensity (watts/cm ²)	Beamlet Spot Size* (microns)	Power Density (watts/atom)	Energy per Target (kJ)	# of Targets	Power Density (watts/cm ³ at STP)	X-ray Pulsewidth (ns)	GasBag Diameter (mm)
1-5	5x10 ¹⁴	3ω - 1780	5x10 ⁻⁵	37.5	48	1.35x10 ¹⁵	18-24	2.6
				75	24			3.3
		2ω - 2380		100	24			"
5-15	5x10 ¹⁵	3ω - 565	2-3x10 ⁻⁴	75	24	6.75x10 ¹⁵	12-16	1.93
		2 - 753		112.5	16			2.2
				150	16			"
> 25	5x10 ¹⁴	1 - 3990	?	125	24		24-30	

*Converging focus onto target is desirable.

NIF Test Capability

The NIF Cold, Warm and Hot potential test capability from laser plasma radiation sources is shown in the next six Tables. The attached view graphs show the calculated debris and graphical overlays (fluence versus area) of the potential test capability and the gold test envelopes presented in previous tables.

**NATIONAL IGNITION FACILITY COLD X-RAY TEST CAPABILITY
(LASER PLASMA RADIATION SOURCES)**

Assumptions: 1.8 MJ, Blue (3ω) Laser, 12-24 Equivalent Point Sources,
Multi-Element, $\pm 10\%$ Uniformity,
Class 100 or Better Contamination Level at Test Object
 ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
0.1-2	900	3-50	50	340*	17,000*	quasi-continuum <10 taps
			5	1,400	7,000	quasi-continuum <1.0 tap
			1	7,000	"	quasi-continuum <0.1 tap
1-6	540	3-50	30	340*	10,000*	lines+continuum <10 taps
			5	830	4,150	lines+continuum <1.0 tap
6-12	270	3-50	15	340*	5,000*	multi-line <10 taps
			5	650*	3,230*	multi-line <1.0 tap

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

**NATIONAL IGNITION FACILITY COLD X-RAY TEST CAPABILITY
(LASER PLASMA RADIATION SOURCES)**

Assumptions: **2.4 MJ, Green (2ω)** Laser, 12-24 Distributed Sources,
Multi-Element, $\pm 10\%$ Uniformity,
Class 100 or Better Contamination Level at Test Object
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
0.1-2	1,200	3-50	50	480	24,300	quasi-continuum <10 taps
			5	4,860	24,300	quasi-continuum <1.0 tap
			1	14,000	14,000	quasi-continuum <0.1 tap
1-6	720	3-50	30	480	14,600	lines+continuum <10 taps
			5	2,900	"	lines+continuum <1.0 tap
6-12	360	3-50	15	480	7,300	multi-line <10 taps
			5	1,460	"	multi-line <1.0 tap

NATIONAL IGNITION FACILITY WARM X-RAY TEST CAPABILITY (LASER PLASMA RADIATION SOURCES)

Assumptions: 1.8 MJ, Blue (3ω) Laser, 12-16 Equivalent Point Sources, Multi-Element,
 $\pm 10\%$ Uniformity, Class 100 or Better Contamination Level at Test Object
 ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
5-15 (2-4 keV BB equiv)	180	3-36	50	100*	5,000*	lines + continuum
			30	130*	4,000*	
			5	450*	2,250*	
			1	1,400	1,400	
10-20 (3-6 keV BB equiv)	90	3-36	25	100*	2,500*	multi-line
			5	280*	1,400*	
			1	700	700	

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

**NATIONAL IGNITION FACILITY WARM X-RAY TEST CAPABILITY
(LASER PLASMA RADIATION SOURCES)**

Assumptions: 2.4 MJ, Green (2ω) Laser, 12-24 Distributed Sources, Multi-Element,
 $\pm 10\%$ Uniformity, Class 100 or Better Contamination Level at Test Object
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
5-15 (2-4 keV BB equiv)	240	3-36	50	100	5,000	lines + continuum
			30	160	4,860	
			5	970	"	
			1	4,800	4,800	
10-20 (3-6 keV BB equiv)	120	3-36	25	100	2,500	multi-line
			5	280	1,400	
			1	2,400	2,400	

**NATIONAL IGNITION FACILITY HOT X-RAY TEST CAPABILITY
(LASER TARGET SOURCES)**

Assumptions: 3.0 MJ, Red Laser (1 ω), Multiple Sources,
 $\pm 33\%$ Uniformity, 250 keV Beam-Target Bremsstrahlung Spectrum
 ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulse width (ns)	Fluence/Dose (cal/cm ²)	Area (cm ²)	Fluence-Area/ (cal)	Dose-Rate	Comments
20-300	7.5	3-15	1.0 0.065	680* 3,000	680* 195		continuum
			kRads(Si)		kRads-m ²	Rads/s	
20-300	7.5	3-15	150 20	1,300 10,000	20	$> 5 \times 10^{12}$	continuum
30-300	6	3-15	150 20	430 3,000	6	$> 5 \times 10^{12}$	continuum

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

**NATIONAL IGNITION FACILITY HOT X-RAY TEST CAPABILITY
(LASER TARGET SOURCES)**

Assumptions: 3.0 MJ, Red Laser (1 ω), Multiple Sources,
 $\pm 33\%$ Uniformity, 250 keV Beam-Target Bremsstrahlung Spectrum
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulse width (ns)	Fluence/Dose (cal/cm ²)	Area (cm ²)	Fluence-Area/ (cal)	Dose-Rate	Comments
20-300	7.5	3-15	1.0 0.1	680 6,800	680 "		continuum
						Rads/s	
20-300	7.5	3-15	150 20	3,000 23,000	46	$> 5 \times 10^{12}$	continuum
30-300	6	3-15	150 20	1,000 7,000	14	$> 5 \times 10^{12}$	continuum

III. OPERATIONAL SCENARIOS

The objective is to identify the criteria for effects test operations on the NIF. Two types of operational plans are to be developed; laser-only and fusion yield. These plans are to evolve from consideration of test scenarios that will consider NIF design, support hardware, and operations. As a result of these test scenarios, the System Design Requirements to support effects testing can be developed with key criteria to include, facility and chamber access, data acquisition, diagnostics, and special requirements.

Sample Operations Plan

In consideration of testing with laser plasma radiation sources, a typical test scenario will be discussed. Assume a moderate area test object such as a sensor seeker system as shown schematically in Figure 2. The size of the complete system to be tested is 300-500 cm². However, the size of the test package to determine hardness will be significantly larger on the order of 1,500-3,000 cm². The complete system presents a challenge for hardness testing as the system is comprised of optical components, precision structural components and electronics. The test object will require testing of the optical components with photons less than approximately 5 keV with an approximation to a 1 keV blackbody near optimum. This test will be discussed as a cold test.

The telescope structure assembly will require testing with photons typically between 5-15 keV. This test will be discussed as a warm test. This test will require active diagnostics of the structural system during and immediately post-test. These active diagnostics will be of two types; 1) a scene generator to observe ability of the system to perform during the test, degree of degradation of system performance and time to recover to full performance and 2) diagnostics of the structure vibrational response which might include a series of holographic snapshots of the telescope assembly pre-, during and post-test.

Shown in Figure 3 is a system developed to support a similar effects test scenario. This is the PORTS system which includes a vacuum chamber, cryogenic environment, power, simulated scene generator and other auxiliary systems. Also note, that in many situations of system development, the test to be performed is not with the full up system and may be a mockup.

A brief discussion of the possible sequence of events leading up to the test and post test activities will be present. Somewhere, there would be a SPO in charge of the project to develop (in this case) a sensor/seeker system. They would contact DNA to confer on the type of tests needed, test protocols, etc. Thus, with the direction of DNA personnel, the SPO would identify the types of test to be performed, the test objectives and start the design of the test canister system. The desired test spectrum, pulsewidth and other test parameters will also be identified.

At this point, to test with the NIF will require a DoD on-site support staff to assist in planning and in development of the test object test canister. In collaboration with the on-site support staff, the SPO will identify required diagnostics, data channels, power, trigger timing, etc. The support staff will interact with the NIF operations, NIF support staff, and the target design group. This interaction will develop:

- 1) Expected test spectrum, pulse-width, etc that are within the available system test operational envelope;
- 2) Specification of target array, laser timing, pointing, shot data(s) acquisition, pre-test procedures, NIF diagnostics, user diagnostics, triggers, power, other, etc., and finally,
- 3) Shot scheduling

The conclusions of the interaction between the NIF personnel and the on-site DoD support staff will result in a possible experimental test plan and this will then be communicated to the User. Clearly, subsequent meetings between the three parties will be required to clarify the test details. Thus, the on-site support staff will require knowledge of expected test capability (manufacture of targets, specification of laser pointing, timing, focusing, trigger timing system, etc).

At the conclusion of the test negotiations, a final test plan will be developed and subsequently the test will be scheduled. Prior to the test the test object, test canister and support systems will be transport to LLNL to a pre-test assembly area and incorporated into a Test Object Transport and Insertion Module. Clearly, the test system will require on-site assembly, setup, check out of systems and this implies the need for a well instrumented, safe, clean work area that will not interfere with standard NIF operations or the preparations for normal NIF operation. It is assumed that this pre-test area is on-site at LLNL but could be either in an area attached to the LTAB or in a separate near-by building.

Prior to the shot day, (perhaps the day before), the test system will be transported on the TOTIM to a pre-test position in a NIF staging area. This would be an area adjacent to the main target area (inside the target building) and this pre-test area would allow for final connections, and diagnostic setup. On shot day, the test system would be moved into the main target area, and all pre-shot preparations that do not require breach of the vacuum chamber will be performed. This would include the data acquisition setup, attachment of signal cables, scope settings, triggers, bias supplies, etc.

Finally, with the final go ahead from NIF operations, the final shot preparations can proceed. This will include:

- Insertion and alignment of target array
- Insertion and alignment of test canister
- Final connection of power, data cables, trigger cables
- Special diagnostic checkout
- Data system checkout

With all systems go, NIF operations would be given the go-ahead. At this point the actual test would be performed and in-situ post testing would follow immediately. After post testing, the test object (canister) would be removed to the post test area and;

- Perform post shot testing (perhaps remove test canister to on-site check out area
- Retrieve data from system to user data analysis system(s)

Finally, the data would be archived, and user data analysis would proceed. The on-site DoD support staff would be de-briefed by the User to review

- Test results, customer satisfaction, problems, etc.
- Recommended corrections and improvements of procedures.

The User would then follow-up with a report and give heads-up on the need for additional testing and future test plans.

The discussion of a test case as described above leads to conclusions about facilitization of the NIF in terms of laser performance issues, engineering issues, space, floor plan, access, power, cabling, chamber vacuum, etc. A presentation entitled "Facilitization Issues of a Conceptual Test Scenario" was presented at the NRSUG meeting held November 29-30 (see attached view graphs). This presentation reviewed the objectives, conceptual test, and conclusions of test area, fluence, spectrum, uniformity, diagnostics and other issues of test support. Also discussed were required facility modifications and conceptual design of a test insertion module to hold and insert the test object into the target chamber.

Figure 2: Schematic of a sample weapon effects test object.

PORTS AGT CONFIGURATION

Figure 3: Ports AGT sensor/seeker test system.

IV. FACILITIZATION ISSUES

Laser Performance Issues

There are several major issues with respect to the use of an array of underdense and dense sources. For 1.8 MJ laser energy, the optimum number of targets is 12-16 and thus 3 to 4 beamlets aimed and focused to each target. The first issue then is targeting and focusing a close packed array near the TCC within the range of limits of the final optical assembly. The need to keep the multiple targets close together raises a second issue of x-ray and debris interaction between targets. A moderate increase in the limits of beam focusing and aiming will significantly reduce the risks associated with these issues.

Significant additional advantages are realized with moderate increase in beam focusing and aiming. For example, preliminary estimates of increasing the beam steering and focusing to allow an array of targets ± 20 cm in the x-z plane orthogonal to the test object axis (assumed to be the y-axis) will increase the warm (5-15 keV) x-ray test capability from 10 cal/cm² over 125 cm² to 10 cal/cm² over 435 cm² or 1 cal/cm² over 1250 cm² to 3.5 cal/cm² over the same area. This would represent a significant increase in warm test capability. Another option to consider is mixing 2ω with 3ω laser irradiation of targets that would allow increased target performance without penalties due to additional optical components. Recall that the 2ω light is focused approximately 24 cm past TCC, thus for those beamlets near the plane of the target array (i.e. x-z axis) only minor refocusing and aiming will be required. This could represent on the order of 16 beamlets (33%) that would require no modification and increase the energy to the target array approximately 13% to 2 MJ. It is recommended that the laser should be capable of focusing 0.35 micron laser radiation to a 500 micron spot at targets at the target chamber center and to individual targets spaced up to ± 25 cm from target center in a plane orthogonal to the axis of a DNA test port and to targets spaced ± 5 cm from the plane. A comparable focusing capability will be for 0.53 and 1.05 micron laser wavelength.

Also, as indicated in the discussion section above, hot-electron bremsstrahlung sources produced by 3 MJ 1ω laser irradiation of targets represents improvements over existing test capabilities in both spectral and temporal fidelity. In particular, the ability to vary the pulse shape to attain more threat-like rise and fall times is an important advancement. Thus, 1ω laser radiation to targets in the target chamber with the maximum available power would add significantly to the NIF NWET capabilities. The development of this test capability will require some level of beam aiming and focusing to optimize these sources, however, the requirements are expected to be less stringent than for distributed underdense sources producing cold or warm x-rays.

The capability for hot-electron bremsstrahlung sources to meet DOE test needs may be somewhat limited with the present assumed performance. These sources have received little attention to date for NWET and improvements in the efficiency with a harder spectrum looks promising and needs to be developed.

Impact of Request for changes in Laser Performance

Facilitization to include the addition of aiming and focusing capability for 1ω and 2ω laser irradiation of distributed targets to allow maximum test utility with laser target sources will have an impact on facility design. Increased laser aiming and focusing for all possible wavelengths is not expected to be without impact to the NIF cost and schedule. Careful coordination between the NWET designers and the NIF project office will be required.

Note that for possible distributed laser target sources the laser beams will be aimed and focused away from TCC. As a consequence, new beam dump locations on the target chamber wall may need to be specified for the unconverted light that will illuminate the chamber wall.

Facility Impact Considerations

In addition to increased beam aiming and focusing, the second major element of facilitization is the proposed addition of a space dedicated to support effects testing. This could be in the LTAB or an attached or separate support building schematically shown in Figure 4. This building will have assembly areas, clean rooms, data analysis areas on the order of 500-1000 ft², offices, meeting rooms, and storage areas. This support area must be interfaced with the NIF as pre- and post-testing, data acquisition and control should be in areas adjacent to the main test area. Thus, space is needed to be designated in the Diagnostic Building for NWET with pre- & post-shot experimental test areas on the order of 1500 ft² or more.

A fundamental requirement for NWET on the proposed NIF is access to a port or ports in the target chamber and for the introduction and positioning of test objects, materials, and diagnostics inside the chamber. A NWET test object could be a single component or a large and complex assembly of many different functional components and subassemblies such as the test described. The test object components and subassemblies are typically electronics, optics, mechanical assemblies, solar panels, and/or cryosystems. They may be contained entirely within a large vessel, or open to a surrounding environment. In some cases the test object's intended functional environment is the vacuum of outer space and could require a precisely matching test environment. However, it is possible that a simple or singular test object (which may be a small subassembly or single component of a system) has operating conditions and a test environment to match those of the target chamber. These could simply be inserted and mounted in the chamber prior to evacuation.

From consideration of the potential x-ray source strength almost all tests would be performed inside the NIF test chamber. A means will be required to quickly and accurately position the test hardware relative to the source location(s). In view of the radiation safety constraints, it is likely that manned access to the NIF chamber would be quite limited, both in occurrences and stay-time. Thus, it is assumed that remote positioning apparatus will be required. This apparatus must be capable of holding potentially large and heavy objects and positioning them with translation accuracy of less than a centimeter and a three dimensional angular orientation accuracy of less than a few degrees anywhere and at any angle in the hemisphere of the test chamber closed to the NWET port. It is assumed in this discussion that this apparatus is the Test Object Transport and Insertion Module (and/or a modified target insertion module).

Figure 4: Schematic of additional test support area needed with facilitization.

The main target area floor to ceiling is 2.74 meters. Assuming that a port flange is a approximately 7.62 cm wide, then this would imply a maximum port size of 2.59 meters. Assuming a test area on the order of 10% smaller to accommodate structure, diagnostics, and signal/control cables, etc., then this would imply a potential test object diameter of approximately 2.33 meters for a test area of 42,700 cm². However, note that in the Target Area design the floor to TCC centerline is 1.067 meters (42") not at one half of the floor to ceiling height of 2.74 meters (1.37 m). Assuming that the source plane is uniformly distributed around TCC, then to utilize a port this size to its full advantage will require to either of two options: 1) tilt the test object such that its axis intersects the TCC (3.47°) with the RTM or with the TOTIM to square up the test object with the source plane, or; 2) redesign the floor of the equatorial test area around this port to accommodate the larger required access.

A complicating factor is the change in the basic NIF design to perform direct drive experiments. To perform direct drive experiments, beamlets from the upper and lower cones will be relocated to 16-24 beamlet ports around the target chamber equator at an angle of $\pm 14^\circ$ from the horizontal plane. The presence of these ports will further complicate the design of a large horizontal axis port for weapon effects testing. A single large port could be designed to encompass the beam port for the direct drive option.

Another potential option is to utilize the 2.3 meter bottom port on the -z axis. Test

assemblies could be mounted on the elevator and inserted into the target chamber. A Re-entrant Test Module (RTM) or a Test Object Transfer and Insertion Module (TOTIM) will be required to provide the vacuum interface and support instrumentation, etc., for the test cassette(s). Note, however, that the present design of the bottom support pedestal limits the size of the support module to approximately 2.25 meters in diameter and the access opening is 1.52 meters wide by 3.04 meters high. Diagnostic cables, vacuum lines, power, cooling, etc. will need to be designed into the NIF to protect this option for NWET.

A third potential option is to utilize the planned neutron flight path diagnostic port located at 110 degrees from the vertical axis. A 2.59 meter port at this location to encompass the neutron flight path diagnostic could be accessed through the lower diagnostic room (-20 degrees). In this test configuration, the test object mounted in a re-entrant test module (RTM) or inserted via a TOTIM must enter the target chamber at an angle on the order of 15 degrees. This test configuration will further complicate beam focusing and aiming for a target array whether a nominal point source or a distributed array. A NWET port at this location would have minimal interference with most NIF operations as the neutron flight path diagnostic is to be used with fusion shots and therefore not interfere with most effects testing except when a fusion capsule is the source. However, clearly, this is not a preferred option.

Many NWET will require test areas on the order of 1500 cm² or less. These tests could potentially be configured to utilize existing TIMs and could therefore, have no effect on the NIF operational schedule. To support NWET and to maintain the advantages of separation of effects testing from standard NIF experiments an equivalent TIM with a possible test area of 1500 cm² or larger mounted in the large NWET port and designed for effects testing would be advantageous.

For large test objects or the use of the TOTIM (or equivalent) will require modifications in the test area floor structure to support higher loading and the large size. In addition, the target chamber door size will be needed to be increased to allow access of large test objects and/or TOTIM (~12 ft). This door should access directly to the adjacent diagnostic support area with a clearance of approximately 15 feet wide and 9-10 feet high. Consequently, this door will need to be automated.

To accommodate possible tests using a LiH scatterer with ignition sources or for neutron experiments with ignition sources will require minor additional modifications to the NIF design. The LiH scatterer assembly could be rolled into the target chamber in a horizontal position through the 2m² door, discussed above, or it could be lifted into the chamber in a vertical position by the elevator. For horizontal motion, the chamber needs to be fitted with a floor of adequate load carrying capacity. For vertical insertion, the load capacity of the elevator needs to be increased from the current baseline of 4.5 tons to about 12 tons.

Radioactivity of the some potential effects test, tests with ignition sources that include a LiH scatterer will require that they be moved by remote control. Following the exposure, these type test/experiments will need to be removed to a shielded room for temporary storage and may be incorporated into the NWET support building. It would therefore be desirable to have a storage vault adjacent to the target area that could accommodate a large activated assemblies and/or other relatively large activated materials.

High vacuum

The test chamber vacuum system is designed to simultaneously evacuate both the target chamber and all diagnostics. It will have the capability of 10^{-6} torr with a pumping rate sufficient to attain the level of 5×10^{-5} torr within 2 hours for the chamber and all diagnostics. The vacuum criteria of many of the NWET tests proposed for the NIF are the same as those defined for the NIF test chamber and diagnostics. The basic requirements for many effects tests are a clean vacuum that will not contaminate the test object, and a vacuum interlock for vacuum isolation between the test object and the target chamber.

The NIF rough vacuum pumping system consists of six oil free vane type forepumps and four Roots blowers. A schematic of the target chamber vacuum system is shown in Nm94-0401-002-0 of the NIF CDR Appendix B. They are sized so that two forepumps and two blowers can rough the chamber down to a pressure of 0.200 Torr in less than 75 minutes. The roughing pumps are manifolded to evacuate the chamber, diagnostics and cryopumps to a single point tritium processing and capture system then vented through the roof. The high vacuum system consists of three 122 cm cryopumps with gate valves to the chamber.

For NWET test objects that have an operating vacuum of 10^{-6} torr, the NWET test modules could use the target area vacuum system in the same manner as some of the test chamber diagnostics. The test module could be connected to the roughing system to rough pump the section external to the target chamber. After this section is roughed down, the vacuum gate valve to the chamber could then be opened. Then the high-vacuum pumping is done through the target chamber.

Very high vacuum

It is possible that NWET optics testing will require higher vacuum criteria than the 10^{-6} torr presently specified for the NIF test chamber and diagnostics. A test object package designed for testing optics could require an operating vacuum of up to 10^{-8} torr. The conditions and operational methods required for a very high vacuum of 10^{-8} torr are an order of magnitude more difficult to attain than for an operating vacuum of 10^{-6} torr. Stringent clean assembly and procedures must be followed. Specialized materials such as stainless steel and O.F.H.C copper are generally used. Very clean pumping systems, provision for systems bakeout, and metal seals, in general, are mandatory. One possible solution for the vacuum differential between the test object and target chamber is to increase the test chamber operating vacuum from 10^{-6} to 10^{-8} torr to match the more stringent vacuum requirements of a test optics package. Vic Karpenko of LLNL suggested that this could be accomplished with addition of large cryo-panels inside the target chamber. Another solution is to isolate the two different vacuum environments with a fast opening valve and use a separate very high vacuum pumping system for the test module. The fast opening valve would be timed to open and expose the test object to the target chamber just prior to the radiation pulse. Another solution that could be designed into a test module is used in the DoD testing module "PORTS" shown in Figure 3. It uses a window to isolate the vacuum environment of the test object and the test chamber. However, note that a window will limit the available x-ray energies to the test object. PORTS was designed for UGT testing, and tests currently performed on AGT simulators.

Figure 5: Schematic elevation of modification to NIF design for facilitization.

Figure 6: Top view schematic of NIF design changes for facilitization.

Figure 5 is a schematic showing an elevation view of the changes in the NIF target area design to allow effects testing for facilitization. Clearly, to accommodate large test objects and its support equipment will require access through the target area to the attached diagnostic support building. Shown in the schematic is an elevator sized to accommodate objects as large as a TOTIM. Also shown is the requirement for basement access for insertion of test objects and/or support requirement via the bottom target chamber port and elevator. Figure 6 shows a top view for facilitization. Note the requirement for a pre/post test area and reinforced floor areas to support the weight of large test objects (i.e., TOTIM). This view also points to the requirement for adequate floor area during the test in the main floor of the target area.

To facilitate tests, the NWET support staff and users will need access to NIF assembly areas and to clean rooms on intermittent basis depending on the effects test schedule (shot sequence) and complexity of the test. This access will also include NIF test support facilities. All effects test sources as outlined will not be simple to manufacture and design. Consequently, NWET will require support from NIF personnel, including theoreticians, engineers designers and technicians for target design and manufacture.

Data Acquisition, Diagnostics & Control

For moderate facilitization will need a dedicated NWET data acquisition & data analysis area on the order of 500 - 1000 ft² each. This system must be integrated into the NIF via a effects tests computer command & control system. The data acquisition needs of NWET programs can cover an extremely broad range. Many passive materials tests will require no active diagnostics. Only post-shot optical analysis and source environment characterization (which may come from existing NIF diagnostics and data acquisition systems) are needed. On the other extreme would be an active electronics test of a major satellite or sensor/seeker subsystem. Channel estimates for such a test range up to 500 channels of various bandwidths. Many of the channels may be specific to a particular class of test object, such as direct digital data recording systems. In these cases, the test user will probably arrive with their own data acquisition systems and umbilical cables for command, control and diagnosis. Such users will often have cable length limitations determined by bandwidth and driver electronics.

Meeting all foreseeable user data acquisition requirements in advance is an unrealistic goal for the NIF. However, system design modification having the flexibility of available space, wireways, power and digitizers to meet the majority of test needs should be implemented.

As discussed in the NIF CDR, the cable run lengths to data acquisition areas is acceptable for essentially all NWET, even for tests with the data acquisition area established in the adjacent diagnostics support building. In addition, the proposed triggering scheme as discussed in the NIF CDR is more than adequate as is the NIF diagnostic grounding scheme. Some effects tests may have active electronics and the x-ray exposure will be desired at a user specified time to synchronize with test unit 'active' state. In addition, some tests may have active diagnostics, or scene generators that may require tester control and synchronization with the NIF control for triggering the laser. Consequently, it is desirable that trigger protocols be established such that a users computer controller would have synchronization with NIF control.

Operations & Management

Thus, facilitization will require changes in the operations and management of the NIF. To support effects testing will require an on-site NWET shot coordinator and on-site support staff and included in the decisions on machine availability and shot priorities. Higher shot rates will require agreements with the NIF support staff to provide target design and manufacturing support and for access to support facilities.

Due to the complexity of the NIF facility and the impact of users on the operation of the facility, managing and planning the integration of NIF and NWET schedules is essential to achieve experimental goals. Addressing all the issues such as experiment cool down times, different vacuum requirements, heat loading to target cryogenics, effects on target position, interference with target diagnostics, debris, and radiation, decontamination, maintenance, and synchronization of both control systems for shot timing is essential to achieve test objectives and will require some type of NWET shot coordinator and an on-site support staff. This support staff must be the interface between the NIF and the tester.

Clearly, minimizing the schedule impacts and conflicts between the NIF and NWET setups can be best achieved with separate areas designated for NWET use. For NWET to be viable with the NIF, the NWET community must be able to be in the loop to gain machine time. Agreements need to be arranged to provide target design and manufacturing support in addition to access to support facilities.

Included in facilitization will be the potential for higher fusion capsule shot rate. This will also have implication on issues related to ES&H of storage and handling activated material in addition to handling of potentially hazardous materials.

V. SECURITY ISSUES

Access to the facility, and all of the areas used by DOD/NWET, data, documents and materials will follow DOD/DOE security codes. Security of data, its processing, handling, transmission and storage will be done in adherence to these codes and procedures. There must be provision for a storage facility to handle up to a Top Secret/SCI DOD DCID 1211 and DoD DIAM 50.3 material. However, interactions with LLNL personnel may require special controls because of DOD/DOE security code variances. Security contingency plans and procedures should be prepared for the event of a possible natural disaster.

Safeguards and Security

The NIF safeguards and security features shall meet the requirements of DOE Order 5632.5, Physical Protection of Classified Matter, for the physical protection of classified matter and items in use and in storage. For the facility security areas and access control, requirements shall be established based on the nature of the experiments (i.e., classified or unclassified) being performed. The limited areas will be in the target area, target receiving and inspection, final target alignment, classified data acquisition, and in office areas in which classified computing is

performed, Automated Data Processing (ADP) systems handling classified information shall meet the requirements of DOE Orders 5637.1, Classified Computer Security Program, and 5300.4C Telecommunications: Protected Distribution Systems.

Because the continuous operation of the NIF is not required to prevent adverse impacts on national security or the health and safety of the public, it is not classified as vital facility, per DOE Order 5332.2A, Physical Protection of Special Nuclear Material and Vital Equipment.

Many NWET experiments will include classified hardware and in addition the experimental data will be classified. The bulk of these classified experiments will be at the S/RD level, however some will involve sensitive, compartmented information where even visual access must be controlled to a few, specially cleared individuals. Special Compartmented Information (SCI) is top secret (TS) information which is separated and maintained within specific functional groups. SCI information mandates access to the information strictly on a "need-to-know" basis. Thus, it is imperative that the offices containing different classes of SCI information be physically separated and acoustically secure. These procedures, when implemented and followed, significantly decrease the probability of information compromise.

For these cases, it would be difficult to clear, e.g., NIF operators and other experimenters working in the general area. Adequate storage, guards, data control, etc. must be provided. This could significantly impact the day-to-day operation and the design of the facility. For example, in some experiments it may be necessary to prevent any electromagnetic signals from uncleared personnel. This may require a dedicated screen room and recording system for sensitive experiments. This possible NIF modification is discussed in the next section.

SCIF Area

NRSUG request for facility modifications to include a screen room and SCIF area are reconsidered. In the NRSUG White Paper, a request was made to include a dedicated DoD data acquisition and data analysis area (600-1000 ft²) as close as possible to the Target Chamber. This user area was requested to be designed to allow up to SCI level test data acquisition. As part of the need to perform SCI tests, a SCIF area estimated at about 5000 ft² to include the user data acquisition area and user setup areas and offices was also requested.

The requests for these areas are a result of consideration of the overall elements to support effects testing. In these considerations, no detailed or fixed design had been formulated, however the functional requirements of a data acquisition and data analysis area is considered critical for the overall effectiveness of the facility to support effects tests. However, as was pointed out by the NIF project and the A/E firm, the inclusion of the capability to perform SCI tests will have a significant impact on the NIF design and operations. The impact will affect the design costs, total project costs and the construction schedule. The impact to operations might at first glance also affect the ability of the facility to meet its primary mission(s).

The DoD community would like to preserve the option of SCI tests. The justification for SCI implies a level of priority and need that it would seem prudent to consider alternatives to preserve this option. A closer look at the test needs indicates that the number and frequency of

SCI future tests that need to be performed on the NIF are few and perhaps far between. There is also the distinct possibility that no SCI level tests will ever need to be performed. It would therefore be appropriate to reconsider the need to maintain the option of a SCI test capability or even the option of a secure working area (upgradable to SCIF). The facility impact on design and operations from maintaining either option appears to overshadow the benefit, particularly if the option to perform SCI tests and to obtain SCI data could be maintained via minor design compromise and emphasis on operations during the time of the SCI tests.

It is proposed, if the above assumptions on the frequency and number of SCI test is true, that an acceptable alternative is available, that would meet the needs of the DoD community and would have minimum impact on facility design and no impact on facility operations except during the time frame of SCI tests. This alternate approach was develop in cooperation with the LLNL Special Security Office. In as much as classified tests are to be performed on the NIF on a regular basis, then certain design, physical and operational safeguards will be implemented as part of the baseline design. If a test is of importance for SCI, then those tests would have a priority to affect the NIF standard operations for the period of the tests including pre- and post-test activities. Thus, requesting and receiving a temporary waiver from the cognizant security authority will permit limited SCI tests under the conditions of the waiver.

Analysis of the facility requirements to perform effects tests has clearly indicated the need of a data acquisition area that would accommodate the effects test user community. The ability to preserve the option of SCI testing in the future can be maintained without the need of a permanently constructed upgradable SCIF area (that include a user data acquisition & analysis area) in the LTAB. Figure 7 shows a conceptual layout of the data acquisition areas. A data conduit from the proposed user data acquisition & analysis area to outside the building to mate with a temporary mobile data acquisition unit has been requested and met with tentative approval from the NIF Project Office. Also, note that a cable tray(s) from the user data acquisition & analysis area to the main diagnostic floor in the target area has also met with tentative approval. The solution is to utilize a mobile data acquisition unit that could be upgraded to SCIF. In the design of the LTAB, it would be requested to incorporate in the design of the cable trays between the target area and the user data acquisition & analysis area and in the conduit to the outside mobile data acquisition unit a separate "locked out" section to be used in the event of SCI tests. In order to allow high frequency data response to be maintained, an intermediate data acquisition "cabinet" could be positioned in the user data acquisition & analysis area. This "cabinet" would only be in position for the SCI tests and at other times the space would be for temporary use. The size for this temporary "cabinet" is estimated to be the width of three full height standard instrumentation racks. This "cabinet" would receive the high frequency SCI data and then transfer it out to the SCIF area.

In review, to preserve the option of future SCI tests, first a waiver of the specific requirements of DCID 1/21 "Physical Security Standards for Sensitive Compartmented Information Facilities (SCIF)", DCID 1/14 pertaining to electronic security and DCID 1/15 pertaining to personnel security must be requested, reviewed and granted. This waiver will describe the operational procedures to allow an SCI test on the NIF to include SCI test objects. All procedure would be under the guidance/oversight of the appropriate security authority. For the SCI tests, the mobile data acquisition unit would be in place and cleared as a SCIF.

Figure 7: Conceptual layout of a multi-use, unclassified screen room for user data acquisition and appropriate safeguards in the conduit and cable trays will allow SCI testing on an infrequent basis.

Appropriate temporary physical and operational changes will be implemented in the diagnostic support building, the main diagnostic area and the target chamber. The conduit locked subsection to the user data acquisition & analysis area would be unlocked and new data and control cables analysis. The use of a mobile data acquisition unit upgradable to SCIF and incorporation of installed as needed. The temporary (SCI cleared) "cabinet" would be installed and interconnected to the mobile unit. The locked subsection in the main user cable tray would be unlocked and new data cables and control cables would be installed as needed. With the operational waivers in effect, the SCI test object could be transported to the LTAB in an appropriate container, brought to the target chamber test area as per the waiver instructions and the test object data acquisition and control cables connected. The test object could then be inserted and tested.

The proposed option will allow the user data acquisition & analysis area to be a multi-use area to include the presence of foreign nationals in all areas without compromising the option of future SCI tests. Also, to preserve this option will have no impact on the baseline NIF operations, and can be implemented with minor design changes to the facility. This approach to allow future SCI tests on the NIF is under review by the LLNL Special Security Office and by DNA Office of Intelligence and Security.

VI. PERFORMANCE/COST/RISK CONSIDERATIONS

In order to evaluate the utility of the NIF for NWET, a cost/benefit/performance evaluation needs to be developed. The issues are first optimization of the source outputs with the best data available, then to determine the cost and schedule impact. Finally, the test utility must be compared to deficiencies in future test needs and priorities associated with the test deficiency that the NIF may fill. This evaluation is expected to develop into a definition of a decision process for assessment of test capability.

The attached Table shows the estimate of facilitization cost. Also included is the potential operational impact to the NIF to allow the use of the requested modifications. An important unexpected cost is in the Additional Design Cost to incorporate the requested NIF design modifications by the NIF project office and the A/E firm.

Risk Assessment

The objective of this preliminary risk assessment is to identify risks to DNA to achieve expected overall test effectiveness and to identify the critical path elements for full facilitization. The risk elements considered were: Project Risk, Source Performance Risk, Source Engineering Risk, Schedule Risk, Cost and Reliability/Repeatability. These risk elements are presented in the attached view graphs.

The conclusions are:

- ▶ FY97 budget is critical. Note that construction starts in FY98.
- ▶ Source performance risk is small (key is successful implementation of distributed sources).
- ▶ Engineering risk associated with design and manufacture of distributed sources. Low laser plasma radiation source debris critical for cold x-ray effects testing.
- ▶ Project is DOE, not DoD, thus completion schedule out of DoD control.
- ▶ Cost risk critical element of potential test utility, negotiations between DOE and DoD needed.
- ▶ No significant risk foreseen with reliability and repeatability.

ESTIMATE OF FACILITIZATION COST

Feature	Additional Capital Cost	Additional Design Cost	Operational Impact
Focus 2 ω (Green) to TCC	\$1M	Small	KD*P
Focus 1 ω (Red) to TCC	\$13.8M	\$50-100K	KDP & KD*P Major Additional Laser Component
Steer Beams ± 25 cm	\$5M	\$250K	Optic Change Over & Alignment
Stack laser pulses to allow 16 successive 3 ns pulses (48 ns total)	\$50K	\$20-30K	None
Screen Room & Instrumentation	\$1M	\$100K	None
Grounding & Shielding	\$250K	\$100K	None
SCIF	\$1.5M	\$150K	Limited Access, Shot Schedule
Additional DoD User Support Areas	\$4M	\$75K	None
Test Chamber & Test Area Mods to include Large Port, Assess Ways	Small	Small	None
Suspend Massive Objects in Chamber up to 2 metric tons	None	None	Install/Alignment Times
Accommodate Cryogenic Test Samples and Active Diagnostics	Small	Small	Increased Shot Setup Time
TOTAL	\$26.6M	\$800K	

VII. SUMMARY OF REQUESTED MODIFICATIONS TO THE NIF

Facilitization will have significant nuclear weapon effects test capability and from cost-benefit considerations should be implemented. The potential cold and warm materials test capability will be an increase or complimentary to other test capabilities. Minor impact facilitization will have minimal impact on the NIF design and operation and additionally, the required design changes or changes in the operational requirements will have no impact on the ability of the NIF to meet its primary mission of fusion ignition.

Laser Performance Criteria

1. *Laser pulse energy at 0.35 microns.* The laser should be capable of delivering 1.8 MJ to a target array configured around the TCC on demand for approved NWET.
2. *Laser pulse wavelength.* The laser should be capable of delivering 0.53 micron energy to the vicinity of target chamber center.
3. *Laser pulse energy at 0.53 microns.* The laser should be capable of routinely producing a temporal shaped pulse of 0.53 micron radiation with an energy of approximately 2.5 MJ to the vicinity of the target chamber center.
4. *Laser pulse wavelength.* The laser should be capable of delivering 1.05 micron energy to the vicinity of target chamber center.
5. *Laser pulse energy at 1.05 microns.* The laser should be capable of routinely producing a temporal shaped pulse of 1.05 micron radiation with an energy of approximately 3 MJ to the vicinity of the target chamber center.
6. *Laser aiming and focusing.* The laser should be capable of focusing 0.35 micron laser radiation to a 500 micron spot at targets at the target chamber center and to individual targets spaced up to ± 25 cm from target center in a plane orthogonal to the axis of a DNA test port and to targets spaced ± 5 cm from the plane. A comparable focusing capability will be for 0.53 and 1.05 micron laser wavelength.
7. *Laser aiming and focusing.* The laser should be capable of focusing 1.05 micron laser radiation to hot-electron bremsstrahlung sources with sufficient power density and energy to allow control of the pulse risetime and pulshape while maintaining a source intensity on the order of 7-10 kJ for photons > 25 keV.
8. *Laser pulsewidth.* The laser should be capable of producing a pulse with an overall duration of up to 60 ns by individual control of beam timing to allow firing delays up to 50 ns.
9. *Machine Time.* Access to machine for NWET on the order of 100+ tests per year.

Functional Requirements

- Option to have beam pointing and focusing to accommodate spaced targets
- Independent beam timing with total pulse width up to 50 ns
- Focusing for 1ω and/or 2ω
- Higher Fusion Capsule Shot Rate

Test Area & Target Chamber Design Criteria

- Order of 2 meter port on horizontal axis for access of 1.5-2.0 meter diameter (nominal) by 6 meter long test cassettes.
- Diagnostic Ports to "look at" the Effects Test Assembly
- Access to port at lower pole
- The test area should be configured to allow easy access of large test cassettes and support apparatus of the order of 2.6 meters high, 4 meters wide by 6-7 meters long weighing up to 5 metric tonnes.
- Floor (strength & space) to accommodate large test module, i.e. the Test Object Transport and Insertion Module.
- Entrance and Egress for the TOTIM (or equivalent system).
Alignment fixtures (Lock-downs) to fix test module to test area structure for alignment of test object in target chamber.
- Adequate access to data acquisition cableways to support most demanding NWET (order of several hundred channels)
- Access to support systems such as vacuum, power, cryogenics, cooling water, etc.
- Vault for temporary storage of activated or special materials with size to accommodate potential large test configurations.

Support Areas & Other Facilities (Access on intermittent basis to:)

- Separate NWET support building with laboratory and office space on the order of 10-20,000 ft². This will include: assembly areas, clean rooms, data analysis area (500 ft²), offices, meeting rooms and storage areas.
- Diagnostic building floor space to include assembly areas and clean rooms.
- Pre- & Post-Shot Experimental Test Areas 1500 ft²
- Data acquisition & Data Analysis Area (500-1000 ft²)
- Effects tests Computer Command & Control
- Access to NIF test support facilities
- Target design and manufacture by NIF personnel
- Maintain experimenter support activity; work stations, telephone, fax, etc.

Data Acquisition, Diagnostics & Control

- Separate NWET Data acquisition & Data Analysis Area (500- 1000 ft²)
- Effects Tests Computer Command & Control
- Cable tray(s) accessible for DoD testing extending between the NWET screen room and

- the target area.
- Instrumentation conduit between NWET screen room to area outside building for Mobil Data Acquisition System (order of 12" diameter).
- Isolated Power and HVAC to Screen Room
- Ground plane (low inductance) on order of 6-10' wide from screen room to target chamber
- Consider EMP isolation of capacitors and capacitor charging supplies.

Operations and Management

- NWET shot coordinator and on-site support staff
- In the loop to gain machine time
- Test and NIF interface
- Agreements to provide target design and manufacturing support
- Agreement for access to support facilities
- Higher number laser target shots for NWET
- Higher Fusion Shot Rate (e.g. 385 MJ increase to 1000 MJ/yr)
- ES&H issues of storage, handling activated material
- ES&H issues of storage, handling hazardous material

VIII. CONCLUSIONS

The present analysis indicates strong argument for DNA to protect maximum potential test capability with the NIF. The NIF has the potential to meet and/or exceed shortfalls in cold and warm x-ray testing for small, medium test areas. Facilitization will have a significant impact on shortfalls in large area and/or high fluence test needs. The present estimate is ~10,000X improvement in clean cold x-ray test capability over existing AGT. For warm x-ray testing, there is no comparison as no x-ray test capability exists. The hot x-ray test capability could satisfy large area SGEMP test capability shortfall.

Additional work required to further identify and quantify risk elements. Specifications of user data acquisition areas, isolation requirements, space, other facility support, etc need to be considered and developed in more detail. Key element of facilitization is the design, manufacture and facility operational impact of distributed sources. These issues need to be addressed in more detail.

FACILITIZATION PERFORMANCE/COST/RISK CONSIDERATIONS

OPERATIONAL SCENARIOS/SECURITY ISSUES

SUMMARY OF REQUESTED MODIFICATIONS TO THE NATIONAL IGNITION FACILITY

**John F. Davis
Alme & Associates**

**NIF Radiation Sciences User Group Meeting
November 30, 1995**

 

INTRODUCTION

PRESENTATION IN THREE PARTS

- I. PERFORMANCE / COST / RISK CONSIDERATIONS
- II. DISCUSSION OF OPERATIONAL SCENARIOS / SECURITY ISSUES
- III. SUMMARY OF REQUESTED DESIGN MODIFICATIONS

PART I: PERFORMANCE/COST/RISK OUTLINE

- 1. PRESENT GOAL TEST ENVELOPE FOR TESTING**
- 2. DISCUSS X-RAY SOURCE POTENTIAL WITH NIF**
- 3. SHOW FRACTION OF GOALS MET WITH DIFFERENT
FACILITIZATION OPTIONS**
- 4. START RISKS ASSESSMENT**
- 5. CONSIDER NIF COST/SCHEDULE IMPACT**

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - COLD

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Fluence (cal/cm ²)	Area (cm ²)	Spectrum Fidelity	Fluence - Area
Cold 0.1 - 6 keV	Surface Effects	Components e.g., mirrors, baffles, solar cells, thermal control surfaces	0.01 - 5	5-50	High Fidelity Clean	10-250
Cold 0.1 - 6 keV	Performance Degradation, Mechanical Damage	Subsystems e.g. optical assemblies, solar panels	0.01 - 1	100-3,000	High Clean	100-3,000
Cold 0.1 - 6 keV	Thermal Structural Response	Telescopes, Seekers	0.5-5	1,000-2,000	Medium	500-10,000
Cold 0.1 - 6 keV	Surface Effects & Blowoff	Phenomenology	5-50	5-100	Medium	500-5,000
Cold 0.1 - 6 keV	Blowoff	RVs, Warhead & Safety Verification	5-50	1,000-5,000	Low	5,000-50,000

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - WARM

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Fluence (cal/cm ²)	Area (cm ²)	Spectrum Fidelity	Fluence - Area
Warm 5-30 keV	TSR, Performance Degradation	Subassemblies Telescopes, Pointer tracker	0.1-5	50-300	Medium	30-1,500
Warm 5-30 keV	TSR, Performance Degradation	Subsystems e.g. Optical assemblies	0.1-5	300-3,000	Medium	500-10,000
Warm 5-30 keV	Thermal effects, bond strengths, new materials, etc	Phenomenology, RV Subsystems	5-50	5-400	Medium	500-10,000
Warm 5-30 keV	Mechanical Response	Missile Subsystems	1-10	1,000-8,000	Low	5,000-50,000
Warm 5-30 keV	Thermo-mechanical Shock	RVs, Pen-aids Missile Bodies,	5-50	1,000-5,000	Low	5,000-100,000
Warm 10 - 60 keV	SGEMP	Strategic Systems and cable assemblies	0.01-0.1	3,000-10,000	High	1,000

GOAL NUCLEAR WEAPON EFFECTS TESTING CAPABILITY - HOT

System, Subsystems, Components & Phenomenology Testing Methodology

Spectral Regime	Test Effect	Typical Test Objects	Dose kRads(Si)	Dose Rate kRads(Si)/ sec	Area (cm ²)	Spectrum Fidelity	Dose - Area KRads(Si)- m ²
Hot 30 - 300 keV	Electronics	Components	50-150	5.0×10^{12}	1-100	Medium-High	0.01-0.15
Hot 30 - 300 keV	Electronics	Ensembles	10-50	$2-3 \times 10^{12}$	100-1,000	Medium-High	0.5 - 5
Hot 30 - 300 keV	Electronics	Subsystems & System	10-50	1.0×10^{12}	1,000-10,000	Medium-High	5 - 20

NIF SPANS FULL RANGE OF X-RAY TEST REQUIREMENTS

TEST
DIRECTORATE

NIF TEST CAPABILITY WITH FUSION YIELD

TEST
DIRECTORATE

TARGET ISSUES

LASER PLASMA RADIATION SOURCES

ASSUMED LASER PARAMETERS

Laser Frequency	Laser Energy (MJ)	Pulsewidth (ns)	Energy/Beamlett (kJ)	Power/Beamlett (watts)
Blue - 3ω	1.8	3	37.5	1.25×10^{13}
Green - 2ω	2.4	4	50	"
Red - 1ω	3.0	5	62.5	"

LASER PLASMA RADIATION SOURCE PARAMETERS

X-ray Source (keV)	Beam Intensity (watts/cm ²)	Beamlett Spot Size (microns)	Power Density (watts/atom)	Energy per Target (kJ)	# of Targets	Power Density (watts/cm ³)	X-ray Pulsewidth (ns)
1-5	5×10^{14}	3ω - 1780 2ω - 2380	5×10^{-5}	37.5 75 100	48 24 24	1.35×10^{15}	18 - 48 18 - 24
5-15	5×10^{15}	3ω - 565 2ω - 753	$2-3 \times 10^{-4}$	112.5 150	16 16	6.75×10^{15}	12 - 18
> 25	5×10^{14}	1ω - 3990	-	125	24		24-30

NIF's maximum potential as a simulator comes from a combination of good source efficiency and effective utilization of the energy produced

Test constraint: Flux uniform to $\pm 10\%$ over test object

Requiring uniformity gives multiple laser sources a conceptual advantage over traditional point sources

Fluence Area

product (or area of $\pm 10\%$ flux @ 1cal/cm²)

$$= \frac{\text{source output}}{\text{sr}}$$

X

**debris shield
attenuation**

X

**solid angle
for 80%
uniformity**

point source	0.45 sr
4-point source	1.6 sr
25-point source	4.5 sr
planar source	2π sr

***With 192 beams, NIF could make a large number of independent sources**

***Tradeoff: Individual source efficiency rises with energy/source;
solid angle falls w/ energy/source (fewer sources)**

LASER PULSE STACKING BEAM AIMING & FOCUSING ISSUES

**192 LASER BEAMS ARRANGED IN
2x2 Beamlets (37.5 kJ each)**

Example: 16 Targets

Blue 3ω Laser Irradiation

3 Beamlets / Target - 112.5 kJ, 3 ns Pulse

Circular Target Array

50 cm Diameter $\Rightarrow$ 9.8 cm Apart

Flexible X-Ray Pulse Shape

t_0 1st Array of Equally Space Targets

+3ns 2nd Array

+6ns 3rd Array

+9ns 4th Array

Total X-ray Pulse 12-13 ns

ASSESSMENT OF X-RAY SOURCE POTENTIAL WITH NIF

FOUR DIFFERENT BEAM TARGET SCENARIOS CONSIDERED

- OPTION 1. Baseline Blue 3ω Laser, 1.8 MJ to Sources Spaced up to ± 5 cm
- OPTION 2. Green 2ω Laser with 2.4 MJ to Sources Spaced up to ± 25 cm
- OPTION 3. Red 1ω Laser with 3 MJ to Sources Spaced up to ± 5 cm
- OPTION 4. Red 1ω Laser with 3 MJ to Sources Spaced up to ± 25 cm

CALCULATED DEBRIS TEST ENVIRONMENT FOR COLD X-RAY EFFECTS TESTING

TYPICAL NOVA LASER
UNDERDENSE SOURCE
Target Mass ≈ 0.1 mg

4000 Å CH membrane filled
with 1 atm of Xe + CH gas

UNDERDENSE X-RAY SOURCE IMPLUSE
12-16 Targets, Total Target Mass of 5.6 mg
Impulse less than 1.0 tap a t > 50 cm
Ratio of 5 cal/cm² per tap

15 MJ IGNITION CAPSULE TEST CAPABILITY

15 MJ YIELD

1.85 MJ X-RAYS - $F \times A = 13,000$ cal

1.6 MJ DEBRIS ENERGY

DEBRIS 50x GASBAG ARRAY

**15 MJ Fusion Yield
Cold X-ray Fluence**

Taps on Test Object

LASER PLASMA RADIATION SOURCES FOR 1-5 KEV X-RAYS

LASER PLASMA RADIATION SOURCES FOR 5-15 KEV X-RAYS

LASER ACCELERATED ELECTRON BREMSSTRAHLUNG

3 MJ, 1.05 micron Laser, +/- 33% Uniformity

Fluence X-Rays > 20 keV

Distributed Source FxA = 680 cal,
Factor of 500X over Current Capability

Dose X-Rays > 30 keV

NIF POTENTIAL TEST CAPABILITY

TEST
DIRECTORATE

CONCLUSIONS OF TEST CAPABILITY ASSESSMENT

- UNDERDENSE SOURCES HAVE REVOLUTIONIZED ASSESSMENT OF NIF TEST CAPABILITY
- FUSION IGNITION NOT NEEDED
- HIGH X-RAY CONVERSION EFFICIENCY DEMONSTRATED
 - ▶ > 50% for less than 2 keV
 - ▶ 25% for 1-2 keV
 - ▶ 8% for 4-7 keV, Potential improvement of Factor of 3 for $h\nu > 5$ keV
- LOW MASS TARGETS $\Rightarrow$ CLEAN COLD X-RAY TEST CAPABILITY
- MULTIPLE TARGET SOURCES LED TO:
 - ▶ Distributed Sources - Increases FxA over Point Sources
 - ▶ Flexible X-ray Pulse Shape
 - ▶ Tailored X-ray Spectrum
- WITH FULL FACILITIZATION, FACTOR OF 10,000x IMPROVEMENT OVER EXISTING CLEAN COLD TEST CAPABILITY
- FILLS SHORTFALL OF WARM X-RAY TEST CAPABILITY, CURRENTLY NONE

NATIONAL IGNITION FACILITY COLD X-RAY TEST CAPABILITY

(LASER PLASMA RADIATION SOURCES)

Assumptions: 1.8 MJ, Blue (3ω) Laser, 12-24 Equivalent Point Sources,
Multi-Element, $\pm 10\%$ Uniformity,
Class 100 or Better Contamination Level at Test Object
 ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
0.1-2	900	3-50	50	340	17,000*	quasi-continuum <10 taps
			5	1,400	7,000	quasi-continuum <1.0 tap
			1	7,000	"	quasi-continuum <0.1 tap
1-6	540	3-50	30	340	10,000*	lines+continuum <10 taps
			5	830	4,150	lines+continuum <1.0 tap
6-12	270	3-50	15	340	5,000*	multi-line <10 taps
			5	650	3,230*	multi-line <1.0 tap

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

NATIONAL IGNITION FACILITY COLD X-RAY TEST CAPABILITY

(LASER PLASMA RADIATION SOURCES)

Assumptions: 2.4 MJ, Green (2 ω) Laser, 12-24 Distributed Sources,
Multi-Element, $\pm 10\%$ Uniformity,
Class 100 or Better Contamination Level at Test Object
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
0.1-2	1,200	3-50	50	480	24,300	quasi-continuum <10 taps
			5	4,860	24,300	quasi-continuum <1.0 tap
			1	14,000	14,000	quasi-continuum <0.1 tap
1-6	720	3-50	30	480	14,600	lines+continuum <10 taps
			5	2,900	"	lines+continuum <1.0 tap
6-12	360	3-50	15	480	7,300	multi-line <10 taps
			5	1,460	"	multi-line <1.0 tap

NATIONAL IGNITION FACILITY WARM X-RAY TEST CAPABILITY

(LASER PLASMA RADIATION SOURCES)

Assumptions: 1.8 MJ, Blue (3ω) Laser, 12-16 Equivalent Point Sources, Multi-Element, $\pm 10\%$ Uniformity, Class 100 or Better Contamination Level at Test Object ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
5-15 (2-4 keV BB equiv)	180	3-36	50	100*	5,000*	lines + continuum
			30	130*	4,000*	
			5	450*	2,250*	
			1	1,400	1,400	
10-20 (3-6 keV BB equiv)	90	3-36	25	100*	2,500*	multi-line
			5	280*	1,400*	
			1	700	700	

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

NATIONAL IGNITION FACILITY WARM X-RAY TEST CAPABILITY

(LASER PLASMA RADIATION SOURCES)

Assumptions: 2.4 MJ, Green (2 ω) Laser, 12-24 Distributed Sources, Multi-Element,
 $\pm 10\%$ Uniformity, Class 100 or Better Contamination Level at Test Object
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulsewidth (ns)	Fluence (cal/cm ²)	Area (cm ²)	Fluence-Area (cal)	Comments
5-15 (2-4 keV BB equiv)	240	3-36	50	100	5,000	lines + continuum
			30	160	4,860	
			5	970	"	
			1	4,800	4,800	
10-20 (3-6 keV BB equiv)	120	3-36	25	100	2,500	multi-line
			5	280	1,400	
			1	2,400	2,400

NATIONAL IGNITION FACILITY HOT X-RAY TEST CAPABILITY

(LASER TARGET SOURCES)

Assumptions: 3.0 MJ, Red Laser (1 ω), Multiple Sources,
 $\pm 33\%$ Uniformity, 250 keV Beam-Target Bremsstrahlung Spectrum
 ± 5 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulse width (ns)	Fluence/ Dose (cal/cm ²)	Area (cm ²)	Fluence-Area/ (cal)	Dose-Rate	Comments
20-300	7.5	3-15	1.0 0.065	680* 3,000	680* 195		continuum
			kRads(Si)		kRads-m ²	Rads/s	
20-300	7.5	3-15	150 20	1,300 10,000	20	> 5x10 ¹²	continuum
30-300	6	3-15	150 20	430 3,000	6	> 5x10 ¹²	continuum

* Fluence-Area Increased as Sources Are in the near Field (Distributed Source with Factor of 3.5x Increase in Test Area Solid Angle).

NATIONAL IGNITION FACILITY HOT X-RAY TEST CAPABILITY

(LASER TARGET SOURCES)

Assumptions: 3.0 MJ, Red Laser (1 ω), Multiple Sources,
 $\pm 33\%$ Uniformity, 250 keV Beam-Target Bremsstrahlung Spectrum
 ± 25 cm Laser Beam Aiming & Focusing

Photon Energy (keV)	Yield (kJ)	Pulse width (ns)	Fluence/Dose (cal/cm ²)	Area (cm ²)	Fluence-Area/ (cal)	Dose-Rate	Comments
20-300	7.5	3-15	1.0 0.1	680 6,800	680 "		continuum
			kRads(Si)		kRads-m ²	Rads/s	
20-300	7.5	3-15	150 20	3,000 23,000	46	$> 5 \times 10^{12}$	continuum
30-300	6	3-15	150 20	1,000 7,000	14	$> 5 \times 10^{12}$	continuum

FACILITIZATION ISSUES OF CONCEPTUAL TEST SCENARIO

**John F. Davis
Alme & Associates**

**NIF Radiation Sciences User Group Meeting
November 30, 1995**

CONCEPTUAL TEST SCENARIO

- **OBJECTIVE TO DISCUSS TYPICAL TEST SCENARIO TO STRESS ELEMENTS OF FACILITY DESIGN**
- **MODERATE AREA TEST OBJECT REQUIRING:**
 - ▶ Cold X-rays for Surface Material Response Testing, Thermal Effects and
 - ▶ Warm X-rays for Structural Response Testing
- **CONSIDER A LEVEL II INTEGRATION OPTICAL SENSOR SUBSYSTEM**
- **STRENUOUS TEST ENVIRONMENT REQUIREMENTS**
 - ▶ Clean Assembly, Handling, Testing
 - ▶ Cryogenic Focal Plane Array
 - ▶ Continuous High-vacuum in Test Canister
 - ▶ No Thermal Gradients
 - ▶ No Stray Optical Radiation
 - ▶ Pre-shot Testing to Ensure All Systems Working, User Control of Test Object Established
 - ▶ Active Diagnostics During Test, i.e., Scene Generator, Holographic Interferometry
 - ▶ Electronics State and Active Diagnostics Necessitates User Trigger Control
 - ▶ Post-shot Testing

LATS

TYPICAL LATS FEU

Lockheed
LMSC-F16524

UNCLASSIFIED

(U) Examples of Optics Applications

Defense Nuclear Agency

SURVEILLANCE SENSOR

INTERCEPTOR SENSOR

TYPICAL OPTICAL PATH

TYPES OF PASSIVE OPTICAL COMPONENTS

- BAFFLES
- MIRRORS
- OPTICAL FILTERS
- WINDOWS & LENSES

CONCLUSIONS FROM CONSIDERATION OF TEST SCENARIO

AREA

Level II Subsystem Tests of Optics, Structures and Baffle Systems will
Require Minimum Test Areas of 500-600 cm²

Optical Subassemblies $\approx 300 \text{ cm}^2$

UGT Test Cassettes (multiple test objects) $\approx 3,500 \text{ cm}^2$

Seeker Systems $\sim 600 - 1,000 \text{ cm}^2$

Test Cassette $\sim 2- 4,000 \text{ cm}^2$

Surveillance System $\sim 1- 1,500 \text{ cm}^2$

Test Cassettes $\sim 4,000 \text{ cm}^2$

SPECTRUM

Optics, Baffles, Surface Effects

0.5- 2 keV BB equivalent

Thermal Structural Response - TSR

3- 4 keV BB equivalent

CONCLUSIONS FROM TEST SCENARIOS (CONT')

FLUENCE & UNIFORMITY

Optics, Baffles, Surface Effects	0.01 - 1.0 cal/cm ²	±10% Uniformity
TSR	0.1 - 5.0 cal/cm ²	±10% Uniformity

DIAGNOSTICS

Active Diagnostics Important - 10s of Data Channels Required
Active Sensors & Passive Sensors Utilized
Knowledge of Test Environment Very Important
- X-ray Spectrum & Pulsewidth At Test Object
Vacuum, Stray Photon Environment

OTHER ISSUES

Test Command Trigger Important
Control of Test Object Environment Important

SCHEMATIC OF A TEST OBJECT TRANSPORT AND INSERTION MODULE

NIF TARGET AREA FACILITIZATION ISSUES

Conceptual Experiment for DNA application 9/95 NIF

The National Ignition Facility

TEST SCENARIO FACILITIZATION ISSUES

SUPPORT AREAS & OTHER FACILITIES

- **Access Required to:**
Diagnostic Building Floor, Assembly Areas, Clean Rooms, Pre- & Post-Shot Experimental Test Areas (~1500 ft²),
Data Acquisition & Data Analysis Areas (~500 ft²)
- **Access to NIF Test Support Facilities**
- **Effects Tests Computer Command & Control Capability**
- **Maintain Experimenter Support Activities; Work Stations, Computer Interface, Telephone, Fax, Etc.**

OPERATIONS AND MANAGEMENT

- **Effects Test Shot Coordinator and on-Site Support Staff Needed**
- **DoD Needs to be In the Loop to Gain Machine Time**
- **Agreements to Provide Target Design and Manufacturing Support**
- **Agreements for Access to Support Facilities**

NIF FACILITIZATION: SECURITY ISSUES

**NIF RADIATION SCIENCES USER'S GROUP
MEETING**

NOVEMBER 29-30, 1995

**JOHN F. DAVIS - ALME & ASSOCIATES
Lt Col CLARK MYERS - DNA/HQ**

ACKNOWLEDGE:

**Ms. Rita M. Metro - DNA Office of Intelligence and Security
Mr. Anthony Cole - LLNL Technical and Physical Security Officer
Mr. Doug Anderson - LLNL Alternate Special Security Officer**

OBJECTIVES

- CLARIFY AND UNDERSTAND IMPLICATIONS OF TESTING OF CLASSIFIED SYSTEMS AND ACQUIRING CLASSIFIED DATA
- SECURITY ELEMENTS INCLUDE
 - ▶ PHYSICAL
 - ▶ PERSONNEL
 - ▶ TELE-COMMUNICATIONS & COMPUTER INTERFACING
- LEADS TO SPECIFICATION OF FACILITY MODIFICATIONS REQUESTED TO MEET DOD NWET NEEDS

NIF GENERAL DESIGN FEATURES

SAFEGUARDS AND SECURITY

- NIF Will Be Designed with Safeguards and Security Features to Meet Requirements for the Physical Protection of Classified Matter and for Items in Use and in Storage
 - ▶ See DOE Order 5632.5 "Physical Protection of Classified Matter"
- Facility Security Areas and Access Control, Requirements Shall Be Established to Allow Classified Experiments
- These Limited Areas Will Be in the Target Area, Target Receiving and Inspection, Final Target Alignment, Classified Data Acquisition, and in Office Areas in Which Classified Computing Is Performed
- Automated Data Processing (ADP) Systems Handling Classified Information Shall Meet the Requirements of DOE Orders 5637.1, "Classified Computer Security Program", and 5300.4C "Telecommunications: Protected Distribution Systems"

Nuclear Weapon Effects Testing

- **Expected to Include Classified Hardware**
- **For Some Tests, The Experimental Data Will Be Classified**
- **Primarily S/RD Level, However Some May Involve Sensitive Compartmented Information - SCI**
- **SCI Is Top Secret (TS) Information Which Is Separated and Requires Extraordinary Security Safeguards**
- **SCI Physical Security Requires a Special Compartmented Information Facility (SCIF) as Established in Director of Central Intelligence Directive (DCID) 1/21**
- **Implies Need for Separate Area in the NIF for Data Acquisition and Processing**

**DIRECTOR
OF
CENTRAL
INTELLIGENCE
DIRECTIVE
1/21**

**PHYSICAL SECURITY
STANDARDS FOR
SENSITIVE
COMPARTMENTED
INFORMATION
FACILITIES (SCIF)**

APPROVED 30 JANUARY 1994

GENERAL CONSIDERATIONS FOR SCI

- **For DoD Tests, the DoD CSA (Cognizant Security Authority) will Ensure SCIFs Comply with DCID 1/21**
- **The CSA Shall Be Responsible for Providing Construction Advice and Assistance and Pre-approving SCIF Construction**
- **Proper Security Planning for a SCIF Will Be Required to Deny Foreign Intelligence Services and Other Unauthorized Personnel the Opportunity for Undetected Entry**
- **Physical Security Will Be Established to Prevent as Well as Detect Visual, Acoustical, Technical, and Physical Access by Unauthorized Persons.**
- **SCIFs Will Have Personnel Access Control. Non-SCI Indoctrinated Personnel Must Be Continuously Escorted**

SCIF PHYSICAL SECURITY CONSTRUCTION POLICIES

- **CRITERIA GOVERNED BY WHETHER THE SCIF IS:**
 - ▶ Closed Storage,
 - ▶ Open Storage,
 - ▶ Continuous Operations or
 - ▶ Secure Working Areas
- **Secure Working Areas are accredited facilities used for handling, discussing, and/or processing SCI, but where SCI will not be stored**
 - a: Construction must Meet the Specs Set for in DCID 1/21, Chap. 4
 - b: All Perimeter Entrance Doors Alarmed
 - c: No Storage of SCI
 - d: Response Force (<15 Min.) with a Reserve Response Force Available to Assist

PHYSICAL SECURITY REQUIREMENTS COMMON TO ALL SCIFs

- **CONSTRUCTION:** Walls, Floors and Ceiling Permanently Constructed and Attached to Each Other
- **SOUND ATTENUATION:** Walls, Doors, Windows, Floors and Ceiling, Including All Openings,
- **ENTRANCE, EXIT, AND ACCESS DOORS:** Single Primary Access, with Automatic Door Closer, GSA-approved Combination Lock and Access Control
- **VENTS, DUCTS, AND PIPES:** Intrusion Detection System, Treated to Provide Sufficient Sound Attenuation
- **WINDOWS:** Restrict Visual Surveillance, If at Ground Level to Be Covered by an IDS

CONSTRUCTION SPECIFICATIONS

- SECURE WORKING AREAS
- PERMANENT DRY WALL CONSTRUCTION
 - ▶ Walls, Floor and Ceiling Will Be Permanently Constructed and Attached to Each Other. To Provide Visual Evidence of Attempted Entry, All Construction, to Include above the False Ceiling and below a Raised Floor, must Be Done in Such a Manner as to Provide Visual Evidence of Unauthorized Penetration.

PERSONNEL ACCESS CONTROLS

- **AUTOMATED ACCESS CONTROL SYSTEM MUST IDENTIFY AN INDIVIDUAL AND AUTHENTICATE THAT PERSON'S AUTHORITY TO ENTER**
 - ID Badges or Cards with a PIN number, or
 - Personal Identity Verification
- **NO EXPECTED IMPACT TO NIF DESIGN EXPECTED OUTSIDE OF DESIGNATED SCIF AREA**

DECADE UNDER CONSTRUCTION

- Large Area Bremsstrahlung Test Facility
- SCIF Certified Secure Working Area
- Total SCIF area about 5000 ft² Including User Data Acquisition System Screen Room, User Setup Areas, and Offices
- UDAS - User Data Acquisition System Screen Room about 1100 ft²
- CNSC, Classified Network System-Computer
- SCI Network in SCIF Area

BUILDING PLAN VIEW

DECADE SUPPORT BUILDING INCLUDES SCIF CERTIFIED USER DATA ACQUISITION, OFFICES, AND SETUP AREA

NIF FACILITIZATION OPTION TO INCLUDE SCI CERTIFIED USER DATA ACQUISITION, OFFICES AND SETUP AREAS

NIF FACILITY DESIGN IMPACT

- Existing Security Controls (At LLNL) Will Reduce/Minimize Facilitization Impact (Operational)
- No Expected Impact to NIF Design Expected Outside of Designated SCIF Area
- Total SCIF Area Estimated at About 3-5000 ft² Including User Data Acquisition System Screen Room, User Setup Areas, and Offices
- SCIF Requires the Design of Protected Cable Tray(s); Keep a Subsection "Sealed" until SCI Tests. Then Run Clean Cables as Needed
- Cable Tray Sizes, Locations - Dependent on Instrumentation Needs

RECOMMENDATIONS

- **DESIGN AND IMPLEMENT SCIF CERTIFIED SECURE WORKING AREA TO SUPPORT DOD TESTING**
- **SCIF SIZE DEPENDS ON INSTRUMENTATION NEEDS**
- **DNA FACILITIZATION PROJECT TO DESIGNATE DNA REPRESENTATIVE TO INTERACT WITH LLNL SECURITY AND PROVIDE CONSTRUCTION ADVICE AND ASSISTANCE**

ESTIMATE OF FACILITIZATION COST

Feature	Additional Capital Cost	Additional Design Cost	Operational Impact
Focus 2 ω (Green) to TCC	\$1M	Small	KD*P
Focus 1 ω (Red) to TCC	\$13.8M	\$50-100K	KDP & KD*P Major Additional Laser Component
Steer Beams ± 25 cm	\$5M	\$250K	Optic Change Over & Alignment
Stack laser pulses to allow 16 successive 3 ns pulses (48 ns total)	\$50K	\$20-30K	None
Screen Room & Instrumentation	\$1M	\$100K	None
Grounding & Shielding	\$250K	\$100K	None
SCIF	\$1.5M	\$150K	Limited Access, Shot Schedule
Additional DoD User Support Areas	\$4M	\$75K	None
Test Chamber & Test Area Mods to include Large Port, Assess Ways	Small	Small	None
Suspend Massive Objects in Chamber up to 2 metric tons	None	None	Install/Alignment Times
Accommodate Cryogenic Test Samples and Active Diagnostics	Small	Small	Increased Shot Setup Time
TOTAL	\$26.6M	\$800K

RISK ASSESSMENT

OBJECTIVE

- Identify Risks to DNA to Achieve Expected Overall Test Effectiveness
- Identify Critical Path Elements for Full Facilitization
- Risk Assessment Just Starting, Expected to Be an Ongoing Process

ELEMENTS

1. PROJECT RISK
2. SOURCE PERFORMANCE
3. SOURCE ENGINEERING
4. SCHEDULE
5. COST
6. RELIABILITY / REPEATABILITY

PROJECT RISK

- NIF Project Subject to Political Decisions
- NIF Key Element of Science Based Stockpile Stewardship
- KD1 Approved, Continues to have DOE Support
- Full FY96 Budget Approved
- FY97?
- DoD Involvement may Enhance NIF Approval Process

CONCLUSIONS: FY97 Budget Critical. Concrete to Pour in FY98.

SOURCE PERFORMANCE RISK

- **Nominal LPRS Source Performance Demonstrated, No Critical Physics Limitations Identified. Optimization Needed**
- **Ignition Sources yet to be Demonstrated. Risk Involved (Schedule, Reliability)**
- **R&D Priorities to Reduce Source Risks - Concentrate on LPRS:**
 - ▶ **Warm Sources Not Fully Demonstrated**
 - ▶ **3 ns Pulsewidth X-ray Emission Required - 1 ns Demonstrated**
 - ▶ **Green Laser Efficiency Comparable to Blue - Not Demonstrated**
 - ▶ **Multi-line, Continuum Emission Important - Not Demonstrated**
- **Impact on Lower Than Expected LPRS Performance - See Graphs.**
 - ▶ **50% of Expected Source Yield for 5-15 keV with Point Sources Significantly Reduces Warm Test Capability.**

CONCLUSIONS: Source Performance Risk Small with Successful Implementation of Distributed Sources (Engineering Risk)

RECOMMENDATIONS: Protect Option 2 & 4 Beam Targeting Scenarios

LASER PLASMA RADIATION SOURCES FOR 1-5 KEV X-RAYS

EFFECT OF 50% REDUCTION IN PROJECTED TEST CAPABILITY

LASER PLASMA RADIATION SOURCES FOR 5-15 KEV X-RAYS

EFFECT OF 50% REDUCTION IN PROJECTED TEST CAPABILITY

LASER ACCELERATED ELECTRON BREMSSTRAHLUNG

EFFECT OF 50% REDUCTION IN PROJECTED TEST CAPABILITY

3 MJ, 1.05 micron Laser, +/- 33% Uniformity

Fluence X-Rays > 20 keV

Dose X-Rays > 30 keV

Distributed Source FxA = 340 cal,
Factor of 250X over Current Capability

SOURCE ENGINEERING RISKS

- Anticipate Higher Risk of Source Performance with Large Distributed Source Arrays
- May be Hidden Cost and/or Facility Operational Impact with Distributed Source Arrays
- Risk with Target Array Manufacturing, Setup, Targeting
- Critical Engineering Issue: Low Laser Plasma Radiation Source Debris Allows Cold Testing without Debris Shield
- Critical Engineering Issue: Multiple Sources with Independent Firing Sequences

CONCLUSIONS: Distributed Array Performance with Acceptable Debris Environments Must be Demonstrated. Factor of Five Increase in Debris has Minimum Affect in Reduced Cold Clean Test Capability

LASER PLASMA RADIATION SOURCES FOR 1-5 KEV X-RAYS

SCHEDULE RISKS

- Schedule Completion Date out of Control of DoD. Project Delays Possible
- Possible Delays Due to NIF Shakedown & Time to Characterize Sources, Long Delay in Availability of Fusion Ignition Sources
- Scheduled Availability of Cold & Warm Test Capability Same or Before Other Options

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
	KD1 Approved ▲	KD1 ▲	KD2 Detail Design ▲		KD3 ▲			KD3a ▲		KD4 ▲
Conceptual Design	▲	▲								
A/E Selected	CDR	◆			Final					
Design Construction										Facility Complete
Startup Full Operation										◆
DOE Cost (\$M)	12.0	6.0	61.0	191.1	229.1	210.2	223.0	112.9	28.1	Total 1073.

Initial Weapon Effects
Tests (non-ignition)

COST RISKS

- **Facilitization Costs to Modify Existing Design to Support Effects Testing have not been Firmed Up. Multiple Options Available.**
- **Expect Surprises, Cost Escalations, Hidden Support Costs. Risk can be Mitigated by Adequate Oversight**
- **Unforeseen Project Cost/Schedule Penalties may Force Compromise in Potential Test Capability. Forces Issue of Who Pays.**
- **Shot Cost Reimbursement Fee - Must be Cost Effective for User to Test.**
- **Cost Comparison to Expected Test Capability Must be Considered by Director/DNA**

CONCLUSIONS: Critical Element of Potential Test Utility. Risk Reduction Necessary

RECOMMENDATIONS: Negotiations between DOE and DoD

RELIABILITY / REPEATABILITY RISKS

- **Laser Designed to Meet System Performance Required for DOE Mission of Fusion Ignition**
- **Required High System Performance, Laser Performance, Reliability, and Repeatability. Exceed DoD Requirements for Laser Produced X-Ray Sources**
- **Repeatability of Laser Plasma Radiation Sources Needs to be Demonstrated (Engineering, Manufacturing Risks)**
- **Risk in Reliability & Repeatability of Fusion Ignition X-Ray Sources**

CONCLUSIONS: Expect Overall High Reliability and Repeatability, Thus Overall Assessment of Risk to Effects Test Capability is Low.

OVERVIEW OF DNA REQUEST FOR NIF DESIGN MODIFICATIONS TO SUPPORT DoD TESTING

**John F. Davis
Alme & Associates**

**NIF Radiation Sciences User Group Meeting
November 30, 1995**

NIF MODIFICATION CATEGORIES

**NIF BUILDING DESIGN MODIFICATIONS REQUESTED TO SUPPORT DOD TESTING
ARE DIVIDED INTO FOUR CATEGORIES**

- 1. TARGET AREA**
- 2. TARGET CHAMBER**
- 3. INSTRUMENTATION, GROUNDING & SHIELDING TO INCLUDE:**
 - Data Acquisition & Analysis Area**
 - Screen Room**
 - Cable Trays**
 - Power & Isolation**
- 4. SUPPORT AREAS & OTHER FACILITIES TO INCLUDE:**
 - Assembly Areas,**
 - Conventional Storage Areas - Test Objects, Test Fixtures, Spare Parts;**
 - Contaminated Storage Areas - Low Level Activation, Contamination of**
 - Test Object & Fixtures**

TARGET CHAMBER

REQUESTED TARGET CHAMBER DESIGN MODIFICATIONS

- Order of 2 Meter Port on Horizontal Axis for Access of 1.5 - 2 Meter Diameter (Nominal) by 6 Meter Long Test Cassettes.
- Diagnostic Ports (Order of Two) That Can "Look At" the Effects Test Assembly
- Capability to Suspend Massive Objects in Chamber up to 2 Metric Tons
- Accommodate Cryogenic Test Samples and Active Diagnostics

TEST AREA

REQUESTED TEST AREA DESIGN MODIFICATIONS

- Access of Large Test Cassettes and Support Apparatus of the Order of 2.6 Meters High, 4 Meters Wide by 6-7 Meters Long Weighing up to 5 metric Tones (10-12,000 Lbs)
- Floor (Strength & Space) to Accommodate Large Test Module
- Door in Target Area Order of 3.0 Meters High and 4.6 Meters Wide.
- Lift to Bring Test Module from Ground Level to Level of Target Chamber Centerline and Allow Access into the Pre- and Post-shot Test Areas.
- Alignment Fixtures (Lock-downs) to Fix Test Module to Test Area Structure for Alignment of Test Object in Target Chamber.
- Access to Support Systems Such as Vacuum, Power, Cryogenics, Cooling Water, Etc. To Support Test Module.

INSTRUMENTATION, GROUNDING & SHIELDING

- **Dedicated DoD Data Acquisition & Data Analysis Area (600-1000 ft²) as Close as Possible to the Target Chamber. Designed to Allow up to SCI Level Test Data Acquisition.**
- **SCIF Area Estimated at about 5000 ft² Including User Data Acquisition System Screen Room, User Setup Areas, and Offices**
- **DoD Dedicated Cable Tray(s) between Screen Room and Target Area. Configured to Allow Visual Inspection Throughout.**
- **Instrumentation Conduit Between Effects Test Screen Room to Area Outside Building for Mobile Data Acquisition System (Order of 12" Diameter). (Needed for IEMP/TREE Testing)**
- **Effects Tests Computer Command & Control Capability (This Would Include Interconnection to Main Control System)**

INSTRUMENTATION, GROUNDING & SHIELDING

cont'd

- **Isolated Power to Screen Room, Preferably Separate from Laser Power Sources.**
- **Isolated HVAC at Screen Room**
- **Ground Plane (Low Inductance) on Order of 6-10' Wide from Screen Room to Target Chamber**
- **EMP Isolation of Capacitors and Capacitor Charging Supplies (Shielded Enclosures).**

OTHER FACILITIES MODIFICATIONS

REQUESTED SUPPORT AREAS & OTHER FACILITIES MODIFICATIONS

- **Dedicated Test Support Area for Effects Testing (Separate Building?) With Laboratory and Office Space on the Order of 10,000 ft².**

This Area Would Include: Assembly Areas, Clean Rooms (Up to Class 100), Data Analysis Area (600 ft²), Offices, Meeting Rooms, Classified and Conventional Storage Areas. Separate Building or Included into the Design of the Diagnostic Support Building

- **Pre- & Post-shot Experimental Test Areas of Approximately 1500 ft² in Diagnostic Building Adjacent to Target Area**
- **Vault for Temporary Storage of Activated or Special Materials with Size to Accommodate Potential Large Test Configurations. Preferably in the LTAB.**

CONCLUSIONS

- PRESENT ANALYSIS INDICATES STRONG ARGUMENT FOR DNA TO PROTECT MAXIMUM POTENTIAL TEST CAPABILITY WITH THE NIF
- NIF HAS POTENTIAL TO MEET/EXCEED SHORTFALLS IN COLD AND WARM X-RAY TESTING FOR SMALL, MEDIUM TEST AREAS. SIGNIFICANT IMPACT ON SHORTFALLS IN LARGE AREA AND/OR HIGH FLUENCE TESTING.
 - ▶ ~10,000x Improvement in Clean Cold X-Ray Test Capability over Existing AGT
 - ▶ No Comparison in Warm As NO X-Ray Test Capability Currently Exists
 - ▶ Hot X-ray Could Satisfy Large Area SGEMP Test Capability Shortfall
- RISKS APPEAR MANAGEABLE - KEY ELEMENT IS DoD/DOE NEGOTIATION AND COOPERATIVE AGREEMENT
- FACILITIZATION CAN BE ACCOMPLISHED WITH MINIMUM IMPACT TO NIF DESIGN & OPERATIONS