Proposal to Operate the Trident Laser High-Energy-Density Facility as a Resource for Defense Programs

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Executive Summary

This is a proposal to fund and operate Trident in order to host a portfolio of research primarily in support of Defense Programs (DP). Following guidance from ADW, Trident will be funded primarily by ADW Capability funding, supplemented by ADW Campaign Mission Deliverable funding as well as other LDRD and HEDLP projects, and possibly Work for Others (WFO) projects. Trident has an unsurpassed track record as a medium-scale facility, and unique strengths in its scientific capability which we propose be redirected to fulfill four critical roles in the weapons program: 1) Continue its proven role of recruitment and retention of technical personnel; 2) Continue its proven role of testing and staging of diagnostics and experiments to larger HEDP facilities; 3) Refocus its proven role of enabling high impact scientific research towards getting results relevant to DP; 4) Develop today the science and technology that DP will need tomorrow. Trident shall be governed by the Trident Governing Board (TGB). The TGB is composed of the cognizant ADW Program and ADEPS Line Managers. The TGB also sets the campaigns that will be executed, incorporating the advice of the Trident Program Advisory Committee (Trident PAC). The Trident Team Leader implements the schedule and provides the required reporting. Based on the personnel and materials needed to run the facility safely and reliably, as well as the funding available from ADW, the total target funding for Trident in FY12 is $2M, including a $1.784M total contribution from ADW. This funding provides for 36 weeks of experimental run time. Starting from a significant DP-relevant research project mix, the Trident project mix is already evolving towards a more DP-centric agenda. Although not finalized, the FY12 research program has been estimated.

I. Introduction:

The Trident laser is a three-beam laser, with one short-pulse (0.5 to 5 ps) and two long-pulse (0.1 ns to ~ 10 μs) beams. Trident provides unequalled short-pulse contrast, focused laser intensity, and range of pulse length. The Trident facility, classified as an "intermediate-scale " facility, includes two operational target chambers with one under construction, a large suite of diagnostics, and supporting infrastructure within P-24. An experienced and highly capable staff enables Trident to meet operational needs with minimum budget. See Sec. IV for more details.

Trident has served as a workhorse facility for LANL since 1992 under the auspices of the Inertial Confinement Fusion Program. With the opening of new large-scale facilities, the ICF program can no longer solely support Trident financially. During the past four years, LANL expended significant effort to transform Trident into a National User Facility, available to mostly outside users via a peer-reviewed proposal process. This program received good reviews, found tremendous demand from the user community, and delivered unsurpassed scientific productivity. Specifically, experiments at Trident have resulted in over 300 publications, including 20 in the high-impact journals *Physical Review Letters* and *Nature*. Nevertheless, the Office of Science of the Department of Energy and Defense

Programs of the National Nuclear Security Agency decided not to provide explicit funding for the user facility.

To maintain Trident as a viable facility meeting the needs of LANL, it is proposed herein to redirect the scientific program at Trident to support more directly Defense Programs.

II. Mission

Under this funding proposal, the mission of Trident is primarily to support Defense Programs (DP), especially at LANL. Secondary missions include the support of other LANL DOE initiatives and programs, such as LDRD and MaRIE. Tertiary missions include support of Work for Others (non-DOE) programs, and external users proposing meritorious science.

This mission is accomplished by providing experimental time on Trident to projects with the following priority:

- Science & ICF Campaigns, including Joint Program in HEDLP
- Other Directed Stockpile Work
- Laboratory Directed Research and Development (LDRD), MaRIE-related and other DOE programs
- Work for Others (i.e., non-DOE projects)

A primary reason for operating Trident at LANL is to recruit, train, and retain staff in support of Laboratory goals. A limited number of outside user groups will be hosted to support this goal.

III. Proposed body of work

The process to shift the body of work of Trident has started, from one typical of an open User Facility with projects chosen purely on the basis of scientific merit, to one of a programmatically responsive facility. As a starting point, during the User Facility regime, a fraction of the work was already programmatically relevant. Such work is already increasing during this FY, but it'll take time during FY12 to reach a long-term asymptotic level during FY13 and beyond.

In the long term, the body of work will be determined just like for other programmatic facilities, such as PRAD, either via program managers directly funding projects, or via scientific teams developing, advocating and getting funding for research proposals. In order to accelerate that process, P Division management is doing the following:

- engaging Science Campaign Program Managers to better understand their research needs and how may Trident-based work help
- presenting a talk about Trident capabilities in their program management meetings
- directing P-24 scientists to strengthen existing Trident-based proposals to Campaign management
- helping external DP users to reformulate their research proposals to be more responsive to the new mission
- asking our scientists to team up with their colleagues to develop Trident-based DP-relevant research proposals

FY12 is necessarily a transition year, where the body of work will be evolving. This is in part because the change of governance has occurred after some of the programs have

significantly firmed up their plans for FY12 and need to fulfill existing commitments and ongoing work. Nevertheless, based on existing work, new work that is materializing in FY11, and ongoing conversations, we provide this possible body of work for FY12:

1. Laser-Plasma Instability research. A radical new direction for coupling laser energy to an ignition Hohlraum is the STUD (Spike Train of Uneven Duration) pulse concept. It is hypothesized that turning the laser on and off quickly, with a random spatial and temporal pattern, and the resulting plasma relaxation between pulses, will limit Stimulated Raman and Brillouin Scattering, currently (and likely to remain) an issue of concern for ICF. The efficacy of this hypothesis is currently being examined computationally during the summer of 2011. These studies will continue into FY12, with LPI experiments in parallel to benchmark plasma conditions and evaluate the diagnostic approach. Once Trident develops the capability (which requires additional funding) to create and propagate the required laser pulses, interaction studies of STUD-pulses with plasma can begin.

Ultimately, if this approach is determined to be not viable, the research topic will switch to examine the coupling between two or more laser speckles with the aim of benchmarking the VPIC computer code.

The ICF program sponsors this work.

2. Diagnostic Checkout and Development. Using Trident's Ten-Inch Manipulator (TIM) or Six-Inch Manipulator (SIM), Omega and NIF diagnostics can be tested, characterized, and calibrated. LANL demonstrated that confirming operation of its diagnostics on Trident before Omega campaigns increases the diagnostic reliability and data return significantly.

In addition, new diagnostics and techniques can be developed on Trident more easily on Trident than on the larger facilities due to Trident's flexibility, on-site location, and more readily available experimental time.

This work is sponsored by the Dynamic Model Validation (DMV) capability through the funding provided by Campaigns 1, 4, and 10. New diagnostics are directly funded by the individual campaigns. In FY2012, it is expected that the Fresnel Zone Plate project to improve x-ray imaging will be funded by the ICF program. The Multiple Monochromatic Imager (MMI) is being built for NIF by the ICF program and will require testing at Trident in the fall.

3. X-Ray Radiographic Sources for High-Energy-Density Applications. The most common diagnostic tool in HED is x-ray radiography using K-alpha emitters. Surprisingly, many aspects of source generation are not yet understood. A modest set of campaigns would continue the efforts to characterize large-area backlighter sources.

In the future, much higher energy backlighters are required which require short-pulse lasers to generate. A project sponsored by Campaign 4 has collaborated with LLNL researchers to produce reliable sources at energies greater than 20 keV. This work will continue under C4 sponsorship.

In addition, there is an overtarget request in Campaign 1 to develop a short-pulse driven backlighter suitable for a future version of the C1-funded dense-plasma EOS. This future version would be fielded on NIF, and the backlighter would be driven by the ARC short-pulse laser.

4. Material Dynamics. We believe that Trident's long pulse capability makes it an excellent driver of dynamic materials experiments, and we are working with the

dynamic materials community to evaluate its utility to their work. Trident has demonstrated the ability to drive such experiments with direct-drive, indirect x-ray drive and laser-driven flyer plates that can shock thin samples to relatively high pressures with a very large throughput. Moreover, Trident has deployed both standard and novel diagnostics with exquisite synchronization, such as VISAR and TIDI (Transient Imaging Displacement Interferometer). The short-pulse beam can produce extremely bright backlighter sources to radiograph socked samples driven by other means. This capability was exploited in the past by various LDRD and ICF projects, exploring topics such as EOS, spall, and phase changes. Right now, for example, a Trident's campaign by a research group from the Darmstadt Technical University is investigating the melt of diamond-like carbon (of interest as a potential ICF capsule ablator material), to compare the results to various theoretical models.

Technical conversations are ongoing, between Trident and P-24 scientific personnel and other shock-physics experts within P-Division, as well as with Campaign 2 program management. Topics where Trident could play a complementary role relative to traditional gas-gun based EOS work. Moreover, mating traditional drivers, such as a boom-box (to study high-explosive driven systems) or a gas gun (to study EOS), to the excellent Trident diagnostic capabilities is being explored. It is expected that these discussion will bear fruit, and Trident may be used for such research possibly as early as FY12.

5. <u>Fast Ignition by Laser-Driven Ion Beams</u>. This project is sponsored by the Joint Program in HEDLP. Fast Ignition is an attractive candidate for Inertial Fusion Energy (IFE) due to the possibility of driving high-yield implosions. According to calculations, a quasi-monoenergetic C-ion beam at en energy ~ 400 MeV has many advantages over other ignitor schemes, such as electron beams. Based on VPIC simulations, new ion-acceleration mechanisms are capable of producing such beams ultimately, with the right short-pulse drive laser. While Trident cannot produce a beam with all the required properties simultaneously, it can demonstrate the physics and validate the VPIC code. This project has already produced record laser-produced C-ion energies (up to 1 GeV), and record laser-driven proton energies (up to 120 MeV). During FY12, Trident research will concentrate on using compound target with multiple thin foils to shape the laser pulse (~ instantaneous turn on, and off) and thus demonstrate the predicted control of the ion energy spectrum.

6. <u>LDRD Projects</u>. Two LDRD-ER projects that use Trident are funded in FY2012. One is LDRD ER project 20110341ER, *A Compact, Brilliant, Coherent X-ray Source Based on a Dense Relativistic Electron Mirror,* with Principal Investigator Manuel Hegelich, which will be in its second year. This work, and the related work by our collaborators on relativistic high-harmonic generation using solid targets, promises coherent x-ray sources with applicability as a diagnostic for compressed ICF capsules, as well as for material dynamic and warm-dense matter experiments in MaRIE. The other is LDRD project. The second is LDRD-ER 20120259ER, *Laser-Driven Relativistic Mechanics, Radiation, and Ion Acceleration,* with Jim Cobble as PI, to begin in FY2012. Again using Trident's short-pulse capabilities, the generation of electron beams will be recorded using proton radiography. The laser-driven electron beams are the basis for ion-beam and x-ray generation.

Present estimate of shot allocations:

1. STUD pulses for LPI mitigation (C10)	8 weeks
2. Diagnostic Checkout & Development (C10 & C4)	6 weeks
3. X-ray generation (C4)	4 weeks
4. HEDLP: Ion-Based Fast Ignition	8 weeks
5. LDRD	8 weeks
6. WFO	2 weeks
TOTAL:	36 weeks.

IV. Governance

There are three main roles to run Trident or any other research facility: govern the facility, evaluate research proposals, and schedule the campaigns.

Governance: While the Trident facility is managed by Physics Division and funded primarily through the Dynamic Model Validation (DMV) program, it answers to the Trident Governing Board (TGB), composed of program and line representatives. Specifically, the membership shall consist of the Program Managers for DMV, C1, C2, C4, and C10 (ICF), Physics and MST Division Leaders, and the P-24 Group Leader, or their designees. The chair of the board shall be the Physics Division Leader.
The duties of the governing board shall be:

1. Determine yearly allocation of facility time, based on the recommendation of the Trident Program Advisory Committee (Trident PAC)
2. Evaluate performance of the facility against agreed criteria
3. Develop recommendations for upgrades and modifications of the facility in anticipation of future needs
4. Peer-review proposals for major (>$200k) facility upgrades or changes in operations and provide funding recommendations to the Science Campaigns Program Director.

In general, significant decisions concerning scope, funding or technical directions shall be made in concurrence with the Science Campaigns Program Director.

Proposal evaluation: Brief research proposals are required to get time on Trident. Evaluation of those proposals against three criteria (feasibility, relevance to Defense Programs and scientific merit) is the job of the Trident PAC. The PAC has the same membership as the TGB, plus a Trident scientist (as a feasibility expert from the facility point of view), as well as one or two independent knowledgeable scientists from LANL or external, to be named by the Trident TGB.

Scheduling: Physics Division is responsible for detailed scheduling of the facility to optimize facility use and productivity. Physics delegates that responsibility to the Trident Team Leader, with oversight by the P-24 Group Leader. Major changes (in allocation, in users, etc.) will be referred to the board.

V. Operating Budget and Business Model

The estimated minimum personnel budget for operating Trident is based upon experience in operating Trident over the past few years. M&S costs are based on a detailed

budget, provided in the table below. Note that the recurring costs have been scaled for 36-week operation. This M&S budget keeps the facility in good operating order, but it is not enough for any significant upgrades.

M&S Items	**Unburdened cost**	**Comments**
Normal yearly costs		(based on 42-week operation)
Flashlamps	$0	use spares for FY12; usage: 50 lamps/yr @ $500/lamp,
Disk refurbishment	$25,000	8 disks repolished @ $3000/disk
Large optic polishing & coating	$25,000	
Small optical components (lenses, mirrors, cameras, photdiode…)	$20,000	
vacuum pump refurbishment	$5,000	
Hardware (optics mounts, stages, etc.)	$10,000	
Personnel support (office supplies, computers, software…)	$10,000	
Misc equipment repair	$25,000	
Subtotal, normal	**$120,000**	
× (36/42)	0.86	Operate for 36 weeks
FY12 subtotal	**$103,200**	
Non-recurring items		
New focusing parabolas	$75,000	existing ones are dying -- need ~ 1 yr lead time
Fast (>6 Ghz) oscilloscope repair	$20,000	required
Pockells cell repair	$30,000	required
Target chamber target positioner	$25,000	currently using experimenter supplied hardware
subtotal	**$150,000**	
M&S total, unburdened	**$253,200**	
Burden rate	1.45	
M&S total, burdened	**$367,140**	

The personnel and total costs of operating the facility are based on experience in order to ensure the safe and reliable operation of the facility. The funding for the tasks performed by the Trident Team Leader, including reporting requirements, will require 1/4 FTE. The personnel and total costs are shown in the table below:

Projected Trident FY12 costs			
FTEs	Personnel	Cost ($k)	Role
2	Laser Techs	$446	Laser operations and repairs
2	Target Technicians	$568	Assist experimenters, target area IWD PICs,
2	Laser & EE Scientists	$802	Troubleshoot, laser diagnostics, EE, modifications, laser and pulsed-power safety, modifications
0.25	Team Leader	$112	Team Leader, schedule implementation, reporting, target area management, facility oversight
Yearly Personnel subtotal		$1,928	Full 42-week operation
	× (36/42)	0.86	Operate 36 weeks
	FY12 Personnel	$1,658	
	Burdened M&S	$367	
	Total FY12	**$2,025**	

We propose the following funding model, based on Guidance from ADW:

Users and funding sources					
User	**Other Program Funding ($k)**	**ADW Capability + Mission Deliverable Funding ($k)**	**ADW Capability Funding ($k)**	**ADW Mission Deliverable ($k)**	**Remarks**
Campaign 10		$900	$760	$140	14 weeks
Campaign 4		$600	$560	$40	4 weeks
DMV		$284	$284		
HEDLP	$80				8 weeks
LDRD	$80				8 weeks
Work for others	$50				2 weeks
Subtotals	**$210**	**$1,784**	**$1,604**	**$180**	
Total Identified funding:		**$1,994**			

This approximate funding model comes within $30k of covering the estimated expenses for FY12. Any additional revenue generated by Trident through additional users remains at Trident.

VI. Operations

Trident will be operated by Physics Division with day-to-day oversight delegated to the P-24 Group Leader. The Group Leader will be the Responsible Line Manager (RLM) and Security Responsible Line Manager (SRLM). The group leader is responsible for the safety, security, environmental, and fiscal envelope of the facility. The P-24 Group Leader delegates to the Trident Team Leader the day to day management of the facility and communications with program and line managers (reports, schedules, etc.).

With the budget proposed, the facility is expected (assuming optimal conditions) to operate for target experiments 36 weeks per year. Every attempt will be made to maintain

that shot rate of experiments through faster experimental setup, schedule optimization, and other efficiencies. While experiments will not be compromised by this goal, it is recognized that more shots means more data for our scientific research and more experimental campaigns can be executed. It is also recognized that the most-requested statistic for any facility is the total number of shots each year. It is expected that the total number of shots will be about 600 per year. It is understood that in principle, up to 25% of the run time can be used for external users. Physics Division will maintain a Trident web page with the current schedule readily available.

In order to improve operations continuously, a standard questionnaire will be developed and each experiment's Principal Investigator will complete it immediately at the end of each run. The results will be compiled and distributed to the governing board.

Monthly reports on facility performance, usage, and scientific highlights shall be provided to the TGB. The ICF Program Manager, specifically, will include those in the monthly Science & ICF reports. It is also the responsibility of the C10 Program Manager to maintain monthly contact with the facility and to work jointly with the Physics Division Leader to represent Trident to the Science Campaigns Program Director, as needed.

VII. Planning for the Future

Physics Division will develop a roadmap for Trident operations through fiscal year 2017. The plan will include two parts. The first is a plan for operations and staffing. This includes personnel training and replacement, forecast of routine and major maintenance that will be required, and possible upgrades to the facility's capabilities including diagnostic equipment. A second part of this plan will be a detailed cost and resource project plan, to be delivered to the TGB, for completing and commissioning the following important enhancements to Trident's capabilities already identified:

1. Hardware to allow the propagation of STUD pulses, for LPI research.
2. Commissioning the West Target Chamber to add tremendous experimental flexibility and the operational efficiency of setting up one experiment and its diagnostics while executing another
3. New standard laser diagnostics such as wavefront sensor and adaptive optics to enable better laser pulse accuracy, focusability and reproducibility
4. A $f/1$ off-axis parabola focusing optic, to enable up to 9x higher laser intensities, keeping Trident as one of the most intense lasers in the world.

VIII. Conclusion

The Trident laser facility at Los Alamos National Laboratory is a world-class laser facility with highly reliable operation and several unique features that would be difficult and expensive to replicate at other facilities. Trident provides a set of capabilities that are important to Physics Division and Defense Programs. The investment in the Trident laser and associated hardware is about $20M, plus and additional $4M additional for the 12,000 ft^2 building. Based on ADW guidance, we are proposing a funding model for FY12 of $2M/year ($1.8M from the ADW program and the rest from other users) to operate the facility for 36 weeks, and to maintain this capability into the future. Such an investment will help to attract and retain the best scientists, provide a capability to develop and test diagnostics destined for the NIF and OMEGA facilities, and provide a capability to perform high-quality research in support of Defense Programs.