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Identifying strategic technology directions in a national laboratory setting: A case study

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Abstract

We present a case study of strategic technology planning in a large, mission-oriented division of Los Alamos National Laboratory. The Division, Nonproliferation and International Security, was strongly oriented around its eponymous mission. The challenge for our planning process was one of scale: identifying a manageable handful of science and technology thrusts that would drive that mission forward. Based on a detailed analysis of future missions and technology possibilities, we identified three strategic directions: (1) computer-enabled understanding, (2) networked and intelligent sensors, and (3) physics applied to sensors. The lessons we learned apply to strategic planning in other diverse R&D organizations.

JEL classification: O32

Keywords: R&D management; Strategic planning; Nonproliferation; National security technology

1. Background

The 13,000 employees and subcontractors of the Los Alamos National Laboratory, operated by the University of California in northern New Mexico, have a clear mission:

To reduce the global nuclear danger by 1) ensuring the safety and reliability of the nation's nuclear weapons, 2) deterring the global proliferation of weapons of mass destruction, 3) supporting efforts to clean up the environmental legacy of the Cold War, and 4) developing solutions to other national security problems in energy, environment, infrastructure, and health[1].

As the nation's first nuclear weapons laboratory (since 1943), the premier mission of Los Alamos has always been science in support of the nation's nuclear stockpile. However, since the

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[1] As stated in 2002. LANL's current statement of mission is similar.

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end of the Cold War, the second mission has gained steadily in importance. This mission, to deter the global proliferation of weapons of mass destruction, was the raison d'etre for one of the largest operating units at Los Alamos, the 800-person Nonproliferation and International Security (NIS) Division. This unit focused its scientists, engineers, and support staff on a mission:

To deter, detect, and respond to proliferation of nuclear, biological, and chemical weapons of mass destruction.

The Division provided contract R&D services for federal agencies including the Departments of State, Energy, and Defense and NASA. It executed its mission via the research, development, prototyping, and application of technologies required in support of national security.

In the early part of this decade, the Division felt the need to more clearly define and articulate its technology directions. Since September 11, 2001, the Division was busier than ever before serving its national security sponsors, providing its sensor, processing, analysis, and other capabilities to the nation. But, even as busy as they were, they needed to keep ever in mind how new technical initiatives can provide the basis for solving hard national problems in the decade ahead. We therefore undertook a technology planning initiative in 2001–2002. The purpose of this article is to share the successes and lessons learned in that initiative. We indeed succeeded in defining meaningful new directions for the Division. Our experience may be of value to other federally funded research and development centers (FFRDCs) who face similar planning challenges.

The goal of our technology planning initiative was to identify of a handful of science and technology (S&T) thrusts to provide additional focus for our scientists and engineers. If carefully chosen, these thrusts would focus our resources on high-leverage technologies that could be applied to a broad range of customer problems. Our problem as managers was to invent a model to drive that planning process.

2. Inventing a model for technology planning

Rather than apply an off-the-shelf technology planning model, we chose to invent our own, motivated by the specialized nature of our mission and organization. We decided that our planning model would have to meet four criteria.

(1) *The technology planning model would have to identify and take into account the Division's core technology capabilities*. We began with a thorough and comprehensive cataloguing of science and technology capabilities. As Bone and Saxon (2000) outlined in "Developing Effective Technologies Strategies," our enumeration of capabilities included the technical skills and knowledge base of our staff, laboratories and equipment, and the organization that support those capabilities. Because this was a planning exercise, we emphasized not only our existing capabilities, but the capabilities that we could reasonably expect to achieve by extrapolating our existing resources. We enumerated a total of 99 detailed capabilities, which included items such as "nuclear material imaging" and "miniaturized radiation detectors."

(2) *The model must take into account the present and future needs of the organization's diverse customer base*. Each of the 99 capabilities was then compared with present and anticipated future customer R&D needs. This cross-referencing of potential capabilities with possible customer R&D problems was the heart of our planning process. NIS has always been a market-driven and customer-driven research organization. As the international environment changes, Division management must integrate dynamic customer needs with the organization's present and future science and technology capabilities. As an example, after

the events of 9–11, many of the Division's research customers immediately refocused upon technical challenges related to homeland defense.

By creating a matrix of capabilities and current/future customer R&D needs, NIS endorsed what Brunner (2001) described as Proctor and Gamble's strategy of "staying close to the customer" in P&G efforts to develop innovative technology. In this shared focus on customer needs, both P&G and a federally funded national laboratory paid tribute to the close relationship between innovation and market forces.

(3) *The model must incorporate likely future global scenarios impacting national security.* Any investment in technology is a wager for that technology having value in the future external environment. That was the major lesson learned from Schwartz in his account of planning at Royal Dutch/Shell, Smith and Hawken, and others in The Art of the Long View (1996). The continued use of scenarios in planning is a tribute to the concept's staying power.

In the final stages of the selection of its technology thrusts, NIS utilized a set of five future world scenarios, which represented varied possible world conditions impacting U.S. national security. Each of the finalist technology candidates was vetted against the five scenarios to evaluate their relative merit as a technology course for the future. Those technologies that fared well in all scenarios were deemed especially worthy of investment.

(4) *The technology planning model must provide useful input to the Division's strategic business planning*. In his DELPHI studies, Scott described a widely acknowledged "critical link between corporate planning and technology planning (2001)." This was not a trivial issue for NIS. Unlike a company that uses innovation to drive products that large numbers of customers want to buy, NIS often develops technology solutions to one-of-a kind problems owned by a single customer.

A typical R&D challenge for NIS might be, "How can 'spot sources' of radiation be reliably and efficiently detected over a broad geographic area?" Market success would consist of a funded research and development program to: (1) define the operational requirements for a successful solution, (2) translate the technological components of the solution into quantitative terms, (3) develop new detection and analysis schemes, (4) test their performance via simulation and small-scale test, and (5) validate the solution with a full-scale prototype, a test against surrogate sources in a realistic background, and, of critical importance, a path that transitions instrument fabrication and operations to industry and government.

Our technology planning was aimed to identify the R&D programs that might face us in the future, and the capabilities that we would need to solve them. While cognizant of the critical link between business and technology planning, we simplified our planning by addressing the technology component first, leaving the business plan to be refined afterwards. The market-oriented nature of our planning guaranteed that would we focus on technology to address specific national needs. The Division has a long history of being driven by very specific R&D needs of its customers.

3. The planning process

We designed our planning process to meet the requirements above, and fine-tuned as the process progressed. Our biggest challenge was scale. In any organization, the number of potential interactions grows as N^2, where N is the number of members. This scaling holds, also, for the mission—capability complexity of our Division, because both the breadth of technical capability and the number of possible missions scale with the size of our organization. NIS Division was two or three times larger than the average technical division at Los Alamos, thanks to its past business success, and its origin from the merger of three divisions. Planning for NIS is therefore almost an order of magnitude more complex than in smaller divisions.

One clarifying principle lay beneath our process: the separate analysis of missions and capabilities; that is, of the problems we solve and the solutions that we bring. At every step we worked to clearly identify which was which. As is said, one can be part of the problem, or part of the solution, but not both. In fact, both problem and solution, mission and capability, are valid components of the Division, but they are not the same things.

Our size made it challenging to reach our goal of selecting a small number of science and technology initiatives that would be the basis for action. To pick these from the many initiatives that might be imagined, we recruited a large cross-section of the Division technical and management staff (50 people, or more than 5% of the Division) to assist in the following steps:

- Analysis of NIS missions and capabilities
- Identification of mission/capability matches
- Definition of candidate science and technology thrusts
- Vetting the candidate thrusts against anticipated missions
- Down selection and validation of the final thrusts

3.1. Analysis of mission and capabilities

NIS is a mission-driven organization, solving particular problems for specific customers. These missions imply, in turn, specific science and technology capabilities. Although identifying our missions was straightforward, identifying our capabilities posed more of a challenge. Our capabilities tend to be hidden behind our mission. We and our peers tend to perceive us by the missions we take on, rather than the solutions we provide. Our self-identity is that we are an

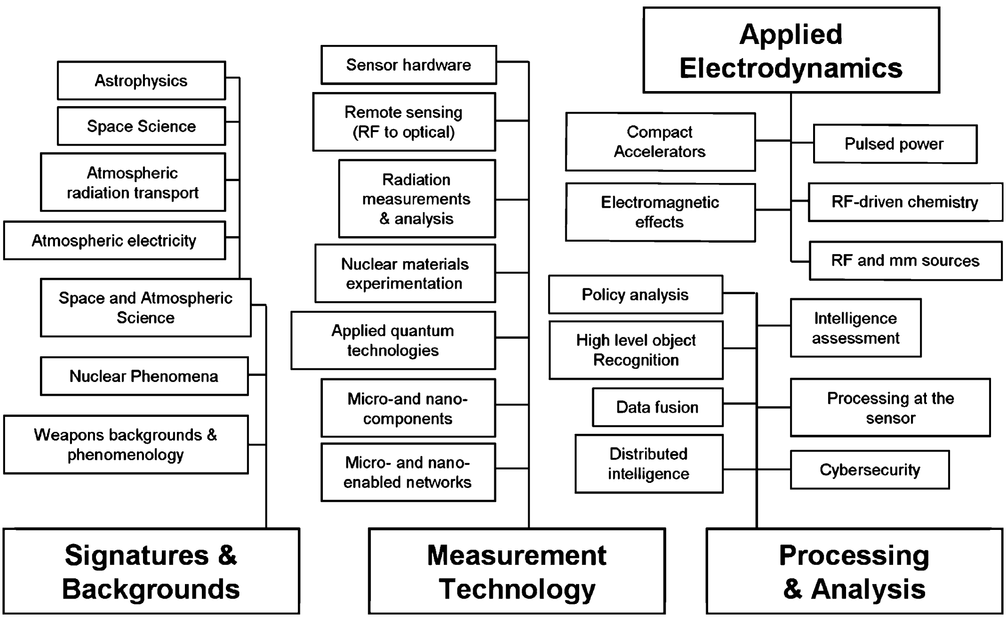

Fig. 1. NIS Division capabilities, present and potential, top levels only.

organization that solves problems in Nonproliferation and International Security, and only secondarily an organization with technical expertise in sensors, processing, and analysis. Although this strong mission orientation is a virtue, since it drives a strong customer focus, we needed to balance our planning process so that it would see both mission *and* capability.

Our inventory started with an assessment of the present and possible futures on both the mission and capability sides. To obtain the appropriate expertise, we drew from every operating Group within the Division to form six mission teams and six capability teams, each consisting of three to five members. The results of their inventories of mission and capability are shown, rolled up to a summary level, in Figs. 1 and 2. At our finest level of detail, we identified 99 potential mission targets (which we called ‘‘R&D gaps’’), and 62 potential science and technology initiatives. An example of this finest level on the capability side is shown in Fig. 3.

3.2. Identification of mission/capability matches

Our next step was to derive potential S&T thrusts by interaction between the mission and capability inventories. This step took the first day of an intense, two-day workshop that involved over 40 technical and management staff. Each mission team spent 50 min with each capability team, discussing the connections between mission and capability. Both sides looked for ways that the capability team’s capabilities could satisfy the mission team’s missions. Every mission team spent time with every capability team. This round robin opened new avenues of communication between Division members, some of whom had little interaction prior to the workshop. Out of their discussions came a detailed understanding of mission/technology connections, and a number of proposed S&T thrusts.

At the end of the first day, we asked each team to put their money where their mouth was. Each capability team was assigned 100 units of capability, representing their people and facilities, while each mission team was assigned 100 units of resource, representing their funding. Each team assigned their resource to a cell in a two-dimensional mission/capability matrix. For

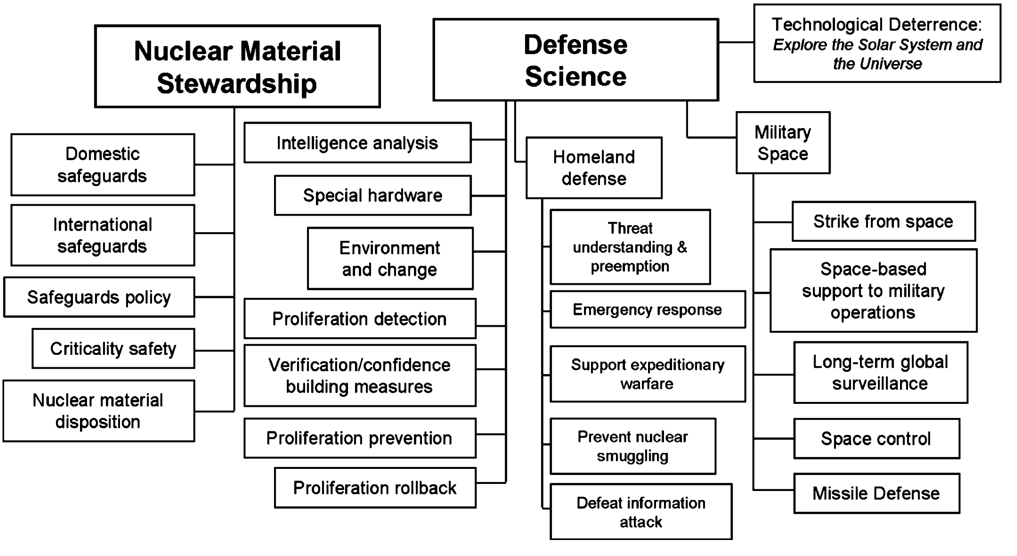

Fig. 2. NIS Division missions, present and potential, top levels only.

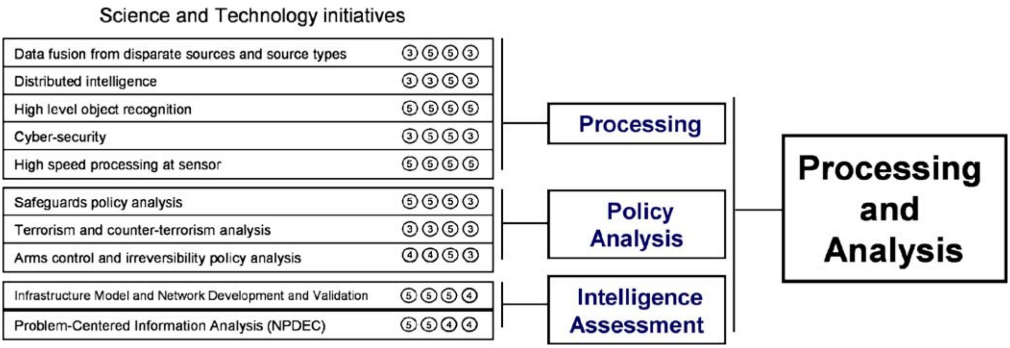

Fig. 3. Detailed breakdown of a fragment of the capability tree.

example, the processing capability team would divide their capability units across the R&D gaps on the mission side. They might invest some of their capability into the S&T initiative ‘‘High-level object recognition,’’ to address the R&D gap ‘‘How do we identify and exclude known culprits?’’ within the Homeland Defense mission.

The mission and capability votes were necessarily sparse across the large (99 R&D gaps $\times$ 62 S&T capabilities) matrix. We then summed the votes along the mission and capability axes, to help select candidate S&T thrusts. An example of these analyses is shown in Fig. 4, which plots

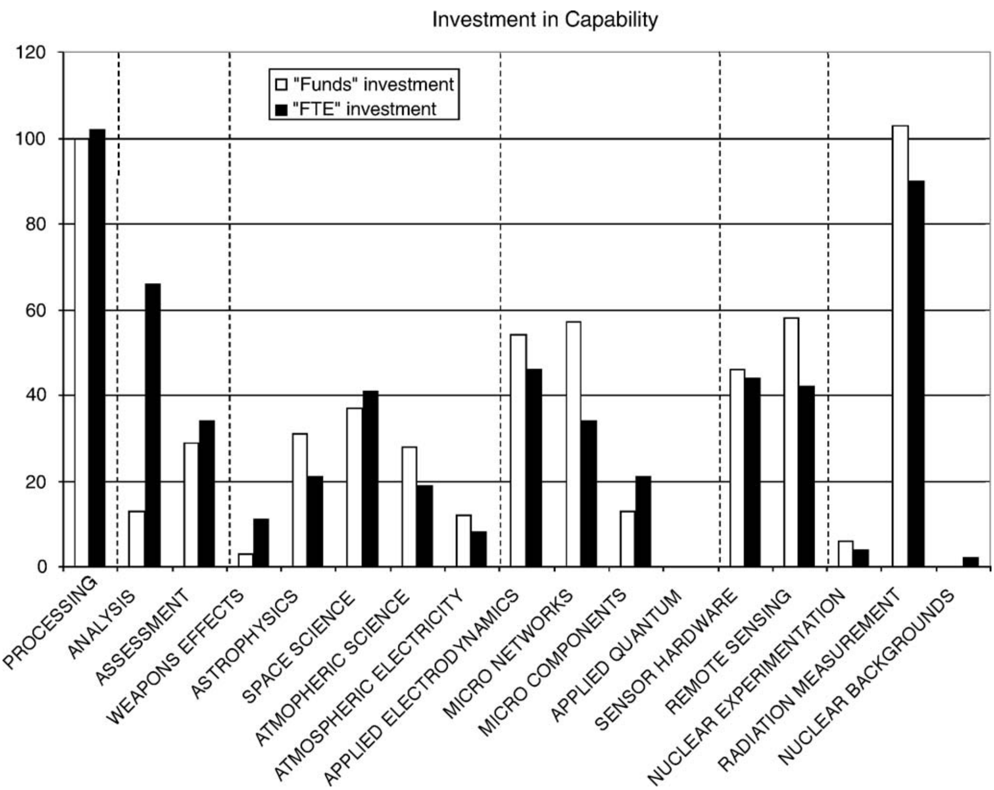

Fig. 4. Investment by mission and capability teams in top-level capability areas.

the investment of capabilities and mission resources into broad mission areas. The mission teams were free to distribute their resources across the board, while each capability team distributed their resources only within S&T initiatives covered by that team (within the narrow vertical lines). The strong correlation between the mission and capability investments, even though the

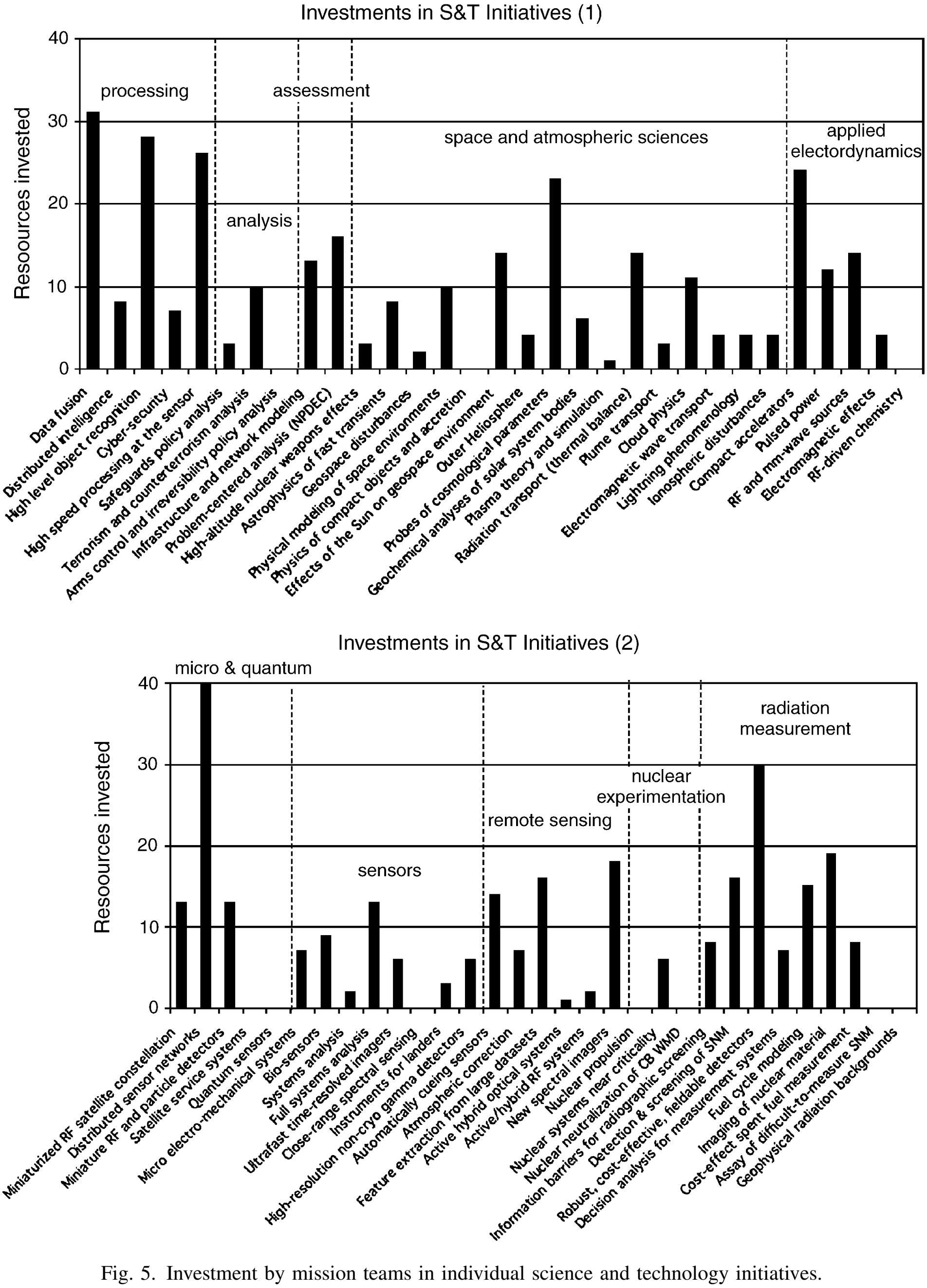

Fig. 5. Investment by mission teams in individual science and technology initiatives.

investments were made by independent teams, is testimony to the integration of mission and capability within our organization.

A finer level of detail of the ‘‘funds’’ investment by the mission teams in the 62 individual science and technology initiatives is shown in Fig. 5. These scores were the raw materials from which we assembled the science and technology thrusts.

3.3. Candidate science and technology thrusts

The mission and capability votes from the teams, combined with their qualitative suggestions, were the starting point for the inductive extraction of eight candidate science and technology thrusts. That is, a small team looked for ways to cluster the science and technology thrusts in a coherent way, with only working titles, looking for related science and technology areas that attracted mission investment. Although perhaps imperfect, we picked enough that nothing critical was likely to have been missed. The choice of candidates was made by a small committee on the evening of the first workshop day, but the next day’s plenary session was unable to suggest any obvious candidates that had been missed. Each thrust was assigned to a new team that named it, defined it, and championed it in the next stages of the workshop (Table 1).

3.4. Vetting the candidate thrusts

We then evaluated the eight candidate thrusts both quantitatively and qualitatively, with a view to understanding their priorities and their connections. Our two-day workshop concluded with a presentation of each candidate thrust by its champions, followed by a discussion of its strengths and weaknesses. At the conclusion of the workshop, participants were invited to vote electronically, to express their prioritization of the candidates. The mean of their rankings is shown in Fig. 6.

The workshop participants, drawn from across the Division, had diverse opinions about the thrusts. When their rankings were averaged, some of the thrusts had statistically equivalent priorities. However, two statistically significant conclusions can be drawn. First, an initiative in the area of networked sensors had broad resonance across the Division. Second, two candidates were clearly less favored. Micro-satellite constellations were downgraded because of the lack of a compelling application, and because of the perceived unlikelihood that Los Alamos could be a leader in a space technology (as opposed to space applications). Systems engineering was perceived as an underlying capability of great value across the Division. Although its value was uniformly affirmed, it was not seen as a focused S&T thrust.

Table 1
Candidate science and technology thrusts

1	Networked sensors for global situational awareness
2	Adaptive real-time sensors
3	Understanding extreme events and environments
4	Information dominance
5	Compact accelerators and RF sources
6	Constellations of affordable micro-satellites
7	Advanced nuclear sensors
8	System analysis

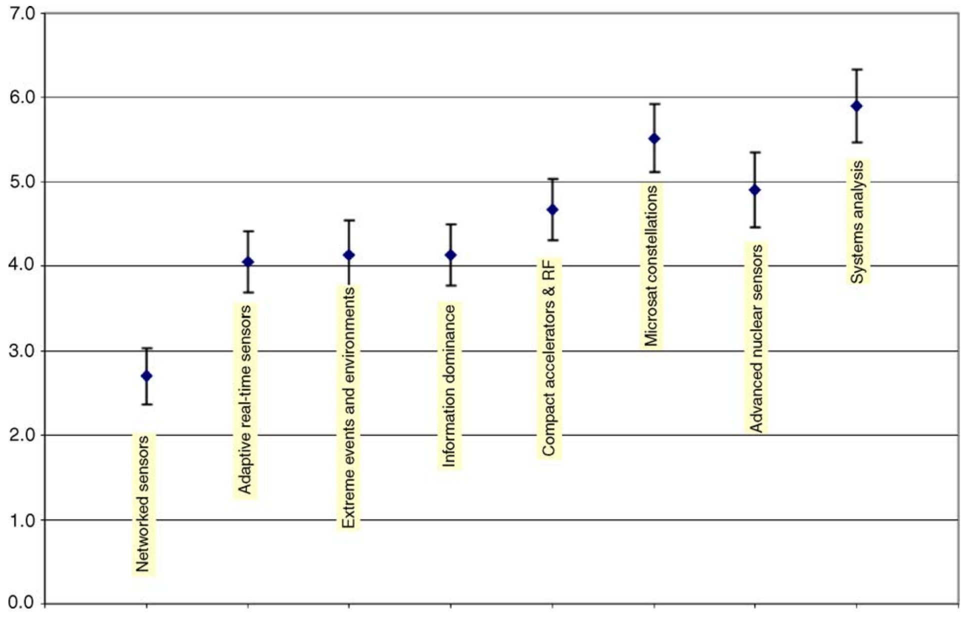

Fig. 6. Mean ordering of the eight candidate thrusts by workshop participants, on a scale from 1 to 8 (1 being the highest score). The error bars are the expected 1-sigma confidence interval for each mean score.

In the time between the two off-site sessions, we broadened our discussions beyond the participants to include senior managers, advisors, and sponsors both inside and outside the laboratory. These discussions were qualitative rather than quantitative. The most valuable insight from these discussions were the connections between candidate thrusts. Most of the outsiders that we interviewed, and many of the workshop participants who voted by e-mail, proposed mergers of the candidates into integrated themes. Their comments showed a large amount of convergence. Some of these connections are mission-inspired, such as ‘‘counter nuclear terrorism’’ and ‘‘global situational awareness.’’ Some are based on the integration of capabilities, notably the popular suggestion that sensor initiatives #1 and #2 be integrated into intelligent networked sensors. Another suggestion was to integrate part of systems analysis (#8) into information dominance. There was a consensus that the strongest basic research element in the Division, astrophysics, space and atmospheric sciences, be treated not as a thrust, but as an underlying capability and a source of people and ideas.

3.5. Down selecting and validating a final set of thrusts

We then reduced the eight original candidates to three finalists, while preserving most of the content of the eight. The finalists were ‘‘networked and intelligent sensors,’’ ‘‘model-driven information dominance,’’ and ‘‘compact accelerators and RF sources.’’ Even the less-popular thrust of ‘‘micro-satellite constellations’’ remained as a candidate basing mode for ‘‘networked and intelligent sensors.’’

The three finalists were reviewed in a half-day follow-up workshop. The review was to determine whether the thrusts met our top-level goals of (1) building on our strengths, (2) driving forward the boundary of the possible, and (3) keeping our eye on the mission.

Table 2
"Future Worlds" used to vet finalist thrusts

1	"Return to normalcy": The world in the year 2007 has settled down to a rerun of the mid-1990s. The war on terrorism and the Israeli–Palestinian conflict are nagging problems but do not pose immediate dangers to U.S. security. Population, energy, and environmental problems are on the horizon, but still not urgent. American priorities have turned back to domestic issues, and economic growth is strong. The national investment in science and technology is increasing in proportion with the growing GNP
2	"Nuclear terrorism": There have been several near-misses when nuclear attacks on CONUS, both radiological dispersion devices and one full-fledged weapon, have been detected and stopped. The detections were by various means, but depended largely on human factors, including smart customs officers and street-wise police. However, in early 2005, a cobalt-60 RDD was detonated in central Miami, with a huge economic and psychological cost although actual casualties were minimal. The nation remains on guard as 2007 dawns
3	"Unchecked proliferation": Both Iran and Iraq have detonated nuclear devices. The new Islamic Republic of Arabia, which incorporates the former Saudi kingdom and several of the oil sheikhdoms, has the interest and resources to obtain nuclear weapons. Its entry into the nuclear club appears imminent. The Israeli–Arab conflict still lacks a solution, and has had several major crises during the decade. During one bout of repeated terrorist attacks sponsored by Syria, the Israelis explicitly threatened nuclear retaliation. As 2007 dawns, there seems to be no limit to the number of nuclear-armed countries in the Middle East. The CIA predicts that at least one of these countries will have an ICBM launcher by 2012
4	"Conventional/bio-terrorism": The September 11, 2001, attack was just the first of a sustained campaign of terror. Suicide bombings like the 2002 campaign against Israel have spread to the U.S. For a 24-month period in 2003–2005, the attacks averaged one per month, and averaged multiple causalities, with a terrible attack killing several dozen in late 2004. It seems impossible to stop the perpetrators from entering the open borders of the U.S. Although the rate of bombings eventually declined, it was replaced by biological terrorism. There were several anthrax attacks reminiscent of the 2001 mailings, then an epidemic of contagious disease in early 2006 that was stopped only by quarantining San Antonio. The attack was discovered only when victims showed up for treatment; its source was never traced. The suicide bomb attacks were carried out by Islamic fundamentalists. State sponsorship was suspected, but never proven to the point where retaliation could be justified. It is now mid-2007
5	"Expeditionary warfare": The U.S. has succeeded in forestalling significant terrorist attacks on its soil, by a series of overseas actions which have disrupted terrorist organizations. However, reaction to these interventions has roused public opinion against the U.S. in much of the Third World. The action in one Asian country has become a prolonged conflict between the U.S.-supported government and guerilla/terrorists. The government was installed by the U.S. to replace a previous state sponsor of terrorism, but it holds only the main cities and coastal plain. Terrorists/guerillas operate freely in the mountainous countryside, with substantial popular and cross-border support. The U.S. military action, based on airpower and special forces, is ineffective against an enemy who blends into the population in villages and regional capitals. Because of this drain on resources and international support, terrorist centers in other countries cannot be addressed. 2007 dawns with no solution in sight

To make the discussions specific, we broke into teams to test the finalists against possible future worlds. Each of five teams was asked to think as if they were in the year 2007. They postulated that the world had taken a certain direction in the next five years, per the scenarios in Table 2. Each team reviewed the validity of the proposed thrusts in the context of their future world. We do not claim to be fortune-tellers, and have no special insight into which scenario will come closest to reality. But by making the scenarios explicit, we helped identify which S&T thrusts would be valuable in a wide range of circumstances.

When the teams reported their discussions, there was a strong consensus that the finalist thrusts were indeed valuable in each of the worlds. The greatest concern expressed was that the thrust on "compact accelerators and RF sources" was too narrow for a Division as broad as ours, and was just one of many possibilities for the application of physics to detectors. Accordingly, the third thrust was expanded to "physics applied to sensors," while the information thrust was renamed ‘‘computer-enabled understanding’’ to differentiate it from the work that intelligence organizations have done since their earliest days.

4. Results of the planning process

Our workshop yielded the technology strategy for our Nonproliferation and International Security Division that is shown, in its mission and capability context, in Fig. 7. The prime objective of our technical work lies in the topmost triangle: *actionable knowledge to neutralize the threat of weapons of mass destruction*. This knowledge supports two missions that are rapidly increasing in importance: Global Situational Awareness and Counter Nuclear Terrorism. Global Situational Awareness is the availability of information about any place, at any time, that facilitates detection of proliferation of weapons of mass destruction, the protection of nuclear facilities, and the support to national action anywhere in the world. Counter Nuclear Terrorism is the protection of the U.S. and allies against nuclear threats, both explosive and non-explosive. To address these missions, our knowledge about the world must be real-time, persistent, networked, far-reaching, and germane.

The steps at the bottom of our figure represent the capability foundations of the Division: our workforce, our facilities, and two special technical areas. These two are (1) systems analysis and engineering, to analyze the systems we develop and the systems against which we collect information, in a consistent, disciplined manner, and (2) basic research, especially in astrophysics and the space and atmospheric sciences. This research provides a wellspring of people, ideas, collaborations, and technologies, to support the S&T thrusts.

Our science and technology thrusts, shown in Table 3, are appropriate for the Division’s role within Los Alamos, as the lead organization for sensors, processing, and analysis. (While processing capabilities are widespread at Los Alamos, NIS Division leads in real-time and deployable processing systems.) Our three science and technology thrusts, the results of our planning process, are shown as the pillars in our diagram.

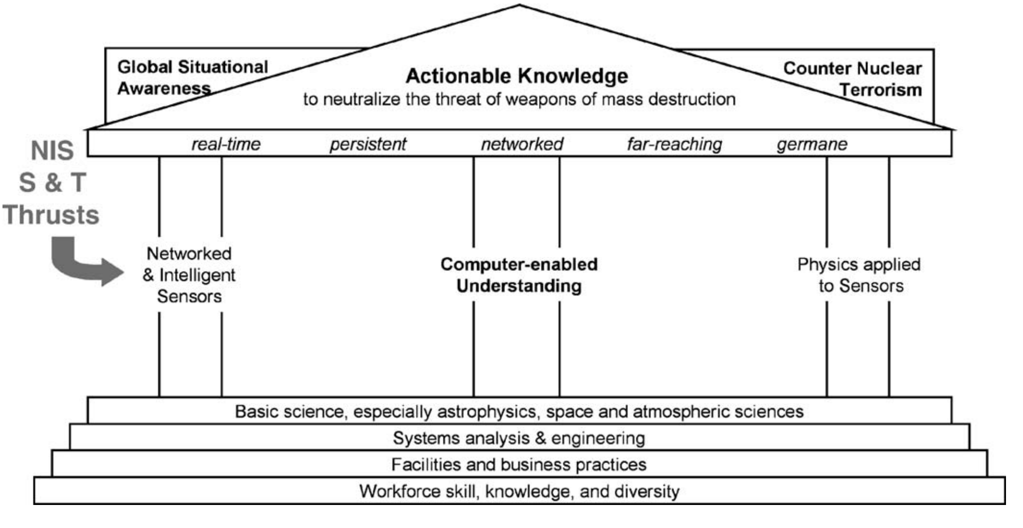

Fig. 7. The NIS Division S&T thrusts (pillars) are aimed at technologies used to produce actionable knowledge of value to the nation.

Table 3
NIS science and technology thrusts

• Computer-enabled understanding
• Networked and intelligent sensors
• Physics applied to sensors

4.1. The importance of computer-enabled understanding

This thrust is defined as:

"Develop vertically integrated systems in which a quantitative model of the subject drives the acquisition of information from massive and heterogeneous data sources, in both the real and cyber worlds, using a variety of automatic tools, and in turn the model is modified by the same information inputs. At the top level of knowledge, the model will be refined by the interaction between human experts and the automated model."

Our #1 prioritization for computer-enabled understanding recognizes the fact that problems often go unsolved not from lack of data, but from the inability to make connections between the data. From our planning exercise, we concluded that NIS had a number of capabilities from which we could build this thrust. Our current capabilities are generally sensor-centric, exploiting our understanding of sensors for the analysis of the data that they produce. To build the thrust, they must evolve to a knowledge-centric approach. In other words, our approach to computer-enabled understanding should increasingly be driven by information pull, rather than sensor push. This step requires increasing expertise in databases, but ultimately, the database, like the sensor, is a tool helping to achieve knowledge and understand goals. Now and in the future, our ability to provide physics insight to the development of knowledge will be a key to our contributions. We remain technology providers for the large part, not operators; our role is to provide tools and demonstrate them, for transition to operators across the government.

4.2. Networked and intelligent sensors

Our second thrust is driven by the functional limitations of existing sensors. The "networked" aspect of the thrust recognizes that by networking sensors, we intend to bypass certain fundamental limits of remote sensing. A large number of signatures – acoustic, nuclear, chemical, biological, and RF, for example – attenuate rapidly with distance. To detect a signature, the sensor must be close, and to cover a broad area, the sensors must be numerous. This implies networks of distributed sensors, which must be economic enough to field in numbers, and therefore miniature. Networked sensors must be able to communicate their message to the user, with early compression of data into the essential elements needed by the user. Each sensor in the network must be able to initialize and operate autonomously.

The "intelligent" aspect of a sensor allows it to manage constrained resources such as bandwidth and processing power. An intelligent sensor is one that reconfigures itself into the appropriate mode for a particular problem, in order to optimize its use of those scarce resources. Generally, networked sensors are smart at the collective level, and intelligent sensors are smart at the individual level, but these classes overlap. Both will be driven forward by technologies such as reconfigurable computing and micro-electromechanical systems (MEMS).

In summary, our second S&T thrust was defined as follows: "Develop a new generation of sensor systems that far exceed present practice in their intelligence and adaptability. This will include distributed networks to sense signatures that are unavailable at long range, and remote-sensing instruments capable of sensing subtle signatures in complex and cluttered backgrounds, with limited resources. Signatures of interest include the nuclear, spectral, chemical/biological, and plasma domains. Platforms will be chosen based on mission need; candidates include facility sensors, deployed ground sensors, unmanned aerial vehicles, and micro-satellite constellations.''

4.3. Physics applied to sensors

Our third thrust is motivated by the realization that much remains to be done in the application of physics to passive and remote sensors, with new possibilities opened up by new materials, micro-fabrication techniques, and the ability to process multiple channels of high-bandwidth data. A particularly attractive opportunity lies in highly miniaturized sources of RF radiation and nuclear particles.

In summary, we defined our third thrust as ''Apply physics to sensor problems in new ways. These include, e.g. the application of new materials to optical, infrared, and nuclear sensing, and the development of intense, compact sources of nuclear particles and RF/mm-wave radiation that enable new solutions in nuclear material detection, communications, remote sensing, and directed energy.''

5. Link between S&T and business plans

In order to bring these three S&T thrusts into reality, an organizational business plan is required, and is in the process of being created. The business plan is the critical link between the science and technology thrust and future day-to-day operations in the Division. This business plan will include a clearly defined set of objectives, and a work breakdown structure to realize those objectives.

6. Conclusions

Looking back on the almost year-long S&T planning exercise, it is clear that some things worked, and some did not. Successes include:

Wide-spread participation. Involvement of large numbers of both technical and management personnel resulted in both a breadth of expertise and extensive communication between people who normally do not share ideas and approaches to customer problems. Without the planning process, these cross-connections would not have taken place.

Identification of a path forward. As intended, the plan generated a small set of S&T thrusts which will be a solid foundation for the Division business plan. Clearly defined business objectives are in the process of being developed. In future conversations with customers and in proposals submitted to sponsors, the organization now has a set of unifying S&T thrusts that will both solve problems and maintain the organization's technological leadership.

Early in the planning process it was clear that some form of revalidation of the selected S&T thrusts must occur on a two- to three-year basis. When the process is revisited, the following changes will be made:

Reduce the length of the process. Now that a baseline has been drawn, it will be possible to shorten the process from a year to three months or less. Because of the length of the process, it became more susceptible to Murphy's Law and the accompanying inevitable delays. Both the aftermath of the massive Cerro Grande forest fire (May 2000) and the events of September 2001 delayed us.

Work at the appropriate level of detail. In the analysis of capabilities and their application to R&D problems, a matrix of size 99×62 was a logistical burden. In the future we will utilize less detail, grouping capabilities and missions into two or three times fewer bins.

Earlier introduction of scenarios. The introduction of future global scenarios in the evaluation of possible S&T thrusts was an excellent tool for narrowing the candidate field. We believe that by introducing this tool earlier in the process, we will tie our planning even more strongly to missions and external realities.

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