SANDIA REPORT
SAND2005-2875
Unlimited Release
Printed May 2005

Transfer of the Neutron Generator Production Mission to Sandia

Lessons Learned for Nuclear Weapons Complex Consolidation and Collocation of Production and Design (U)

Lani Miyoshi Sanders, Eric H. Detlefs, Larry E. Pope, John A. Sayre, Donald E. Waye and Robert G. Spulak

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Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Sandia National Laboratories

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Abstract

Transfer of the neutron generator mission from Pinellas Plant to Sandia National Laboratories was completed in the late 1990s as part of the Nonnuclear Reconfiguration Program, which resulted in removal of the production plants at Pinellas, Mound, and the nonnuclear portion of Rocky Flats from the nuclear weapons complex. Relocating the neutron generator production mission to Sandia resulted in the collocation of production and design, an approach with merits debated over the years. In this briefing package, we utilize the perspective hindsight renders to articulate the key benefits, drawbacks, and lessons-learned from the transfer of neutron generator production to Sandia. We also document the evolution of the mission transfer and give context for the key cost and logistical drivers that propelled neutron generator relocation - and Nonnuclear Reconfiguration as a whole - to become a reality.

Acknowledgements

The authors gratefully acknowledge Lenny Martinez for his support of this product. Chuck Loeber, Tom Bomber, Frank Bacon, Angela Ortiz, Mary Kay Austin, Dexter Boone, Mike McClafferty, Kim Gallagher, and TJ Garner also provided useful insights and supporting data. Finally, the authors thank Linda Branstetter for her technical review of the final product.

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Introduction

Over five years have passed since Sandia officially produced the first war reserve (WR) neutron generators (NG) for the stockpile. While the transfer of the NG mission from Pinellas to Sandia was only one piece of the Nonnuclear Reconfiguration (NNR) program realized in the 1990s, this piece nonetheless represented the largest transfer of a singular production mission to a weapons laboratory (within NNR). The merits of such collocation of design and production have been debated over the years. (For example, in the Stockpile Stewardship and Management Programmatic Environmental Impact Statement, the alternative of moving production missions to the weapons laboratories and the Nevada Test Site was contrasted with the "downsizing-in-place" alternative that was ultimately selected.[1]) As such, an analysis of this transfer with 20/20 hindsight provides a unique, case-specific opportunity to (1) document the evolution of such a mission transfer and (2) articulate lessons-learned for future consolidation efforts.[2]

[1] *Record of Decision, Programmatic Environmental Impact Statement for Stockpile Stewardship and Management* (DOE/EIS-0236), Federal Register Volume 61, No. 249, December 26, 1996.

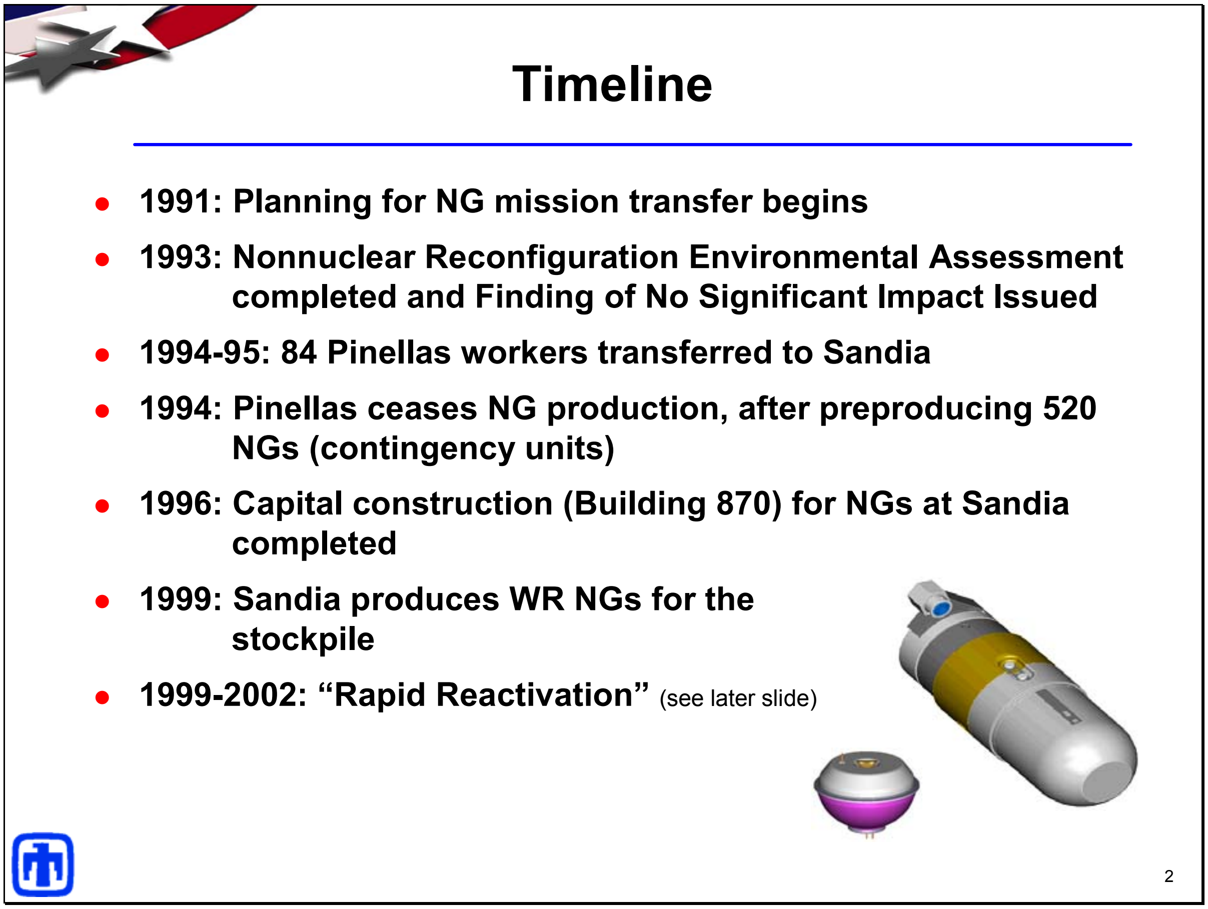
[2] More detailed discussion of the transfer of the neutron generator production mission to Sandia can be found in *Production Mission in a National Laboratory*, Larry E. Pope, to be published.

In February 2005, the Nuclear Weapons Complex Infrastructure Task Force inquired if such an analysis had been completed.[3] Since no formal analysis had been executed since Sandia WR (war reserve) production commenced, Lenny Martinez, Sandia's Vice President for Manufacturing Systems, Science, and Technology, commissioned a small team to perform a quick-turnaround assessment. The team had six days to complete an interim briefing; an abbreviated version of that briefing was given by Lenny Martinez to the Nuclear Weapons Complex Infrastructure Task Force on March 3, 2005. This briefing package includes the slides utilized for the interim study, coupled with explanatory text and supplemental information.

The primary objective of this briefing package is to provide concise, high-level answers to the questions:

- What are the key benefits and drawbacks of collocation of NG design and production?
    - What are the major lessons-learned to be applied to future collocations?
- What impact did stockpile uncertainties have on the NG mission transfer?
    - What are the major lessons-learned for sizing to smaller future stockpiles?
- Was the NG portion of Nonnuclear Reconfiguration cost effective, and how?
    - What are the major lessons-learned for future downsizing of the complex?

[3]The Nuclear Weapons Complex Infrastructure Task Force was requested in the *Report to Accompany H.R. 4614*, submitted by the Commmittee on Appropriations for Energy and Water Development for FY2005 (Representative D.L. Hobson, Chair of House Subcommittee on Energy and Water Development). The Task Force members included Dr. David O. Overskei (Chair), Dr. Hermann A. Grunder, Dr. John C. Crawford, Dr. Robert E. Nickell, and Mr. Donald G. Trost.



Evolution of the Mission Transfer

Closing Pinellas (as a DOE weapons production site) and transferring the NG mission to Sandia was a subset of Nonnuclear Reconfiguration, which itself began as part of Complex-21 and the work of the Privatization Planning Panel (chaired by Chuck Loeber).[4] Both Complex-21 and the Panel concluded that meaningful cost savings could be realized by consolidating nonnuclear missions (i.e., closing nonnuclear sites and transferring their missions to a receiver site) within the DOE weapons complex.[5]

Cost savings estimated for NNR withstood intense political pressure from Florida (Pinellas) and Ohio (Mound Plant) politicians and review by three outside consultants, allowing it to move forward through the NEPA (National Environmental Policy Act) process in 1993.[6] When it became clear the NG mission was headed for Sandia, a list of critical personnel skills was compiled. Personnel from Pinellas were interviewed, and a total of 84 managers,

[4]Complex-21 (documented in the *Nuclear Weapons Complex Reconfiguration Study*, January 1991) had its roots in the *Modernization Report* (December 1988) from the President to Congress.
[5]*Phase 1 Report of the Privatization Planning Panel*, January 1991, and *Nonnuclear Reconfiguration Cost Effectiveness Report*, January 1993.
[6]John S. Foster, Jr., Kenneth L. Woodfin, Terry R. Lash, Reports to Sec. O'Leary, May 21, 1993.

technical staff, and technologists transferred to Sandia throughout the initial stages of NNR. As discussed later in the briefing, this proved an essential step.

In February of 1994, reductions in President Clinton's FY95 budget forced a NNR plan revision, with production at Pinellas (and Mound and Rocky Flats nonnnuclear) to be closed one year earlier. In light of the gap between Pinellas shutdown and projected Sandia WR NG production, the DOE/Albuquerque Operations Office (DOE/AL) requested Pinellas pre-produce an inventory of NGs (contingency units) before closing.

The Sandia Neutron Generator Facility, Building 870, was completed over the span of ~16 months (September 1994 - January 1996) at a cost of ~$62M. After formal documentation of the Readiness Assessment, Building 870 was officially prepared for operational use in March 1997. Once the neutron tube and NG lines were declared WR qualified, 23 functional tests were completed to establish reliability. These tests were successful (no failures) and the first Sandia-produced WR NGs were delivered to bonded storage in advance of the October 1999 FPU (first production unit) commitment.

During the construction of Building 870, it became clear that the NG production capacity would need to support <u>both</u> the Active and Inactive Stockpile, rather than just the Active Stockpile, as originally believed. However, this problem was not addressed prior to startup of WR qualification activities in the facility. As a result, "Rapid Reactivation," in essence an expansion of Sandia's NG capacity (600/yr→1500/yr) through modification to Buildings 870, construction of Building 857B, and expansion of Building 700 (to accommodate development) was completed during production and qualification activities.

Facility Comparisons

1992 Pinellas NG Mission:

- **~600 workers**
- **~186 ksf net manufacturing floor space**
- **Annual budget: ~$86M FY04 ($64M FY92)***
- **Capacity: ~3000 NGs/year (max ~6900)**

Today's Sandia NG Mission:

- **~250 workers**
- **~119 ksf net manufacturing floor space**
- **Annual budget: ~$66M FY04**
- **Capacity: ~1000 NGs/year (max ~1500)**

*U.S. Bureau of Labor Statistics Consumer Price Index

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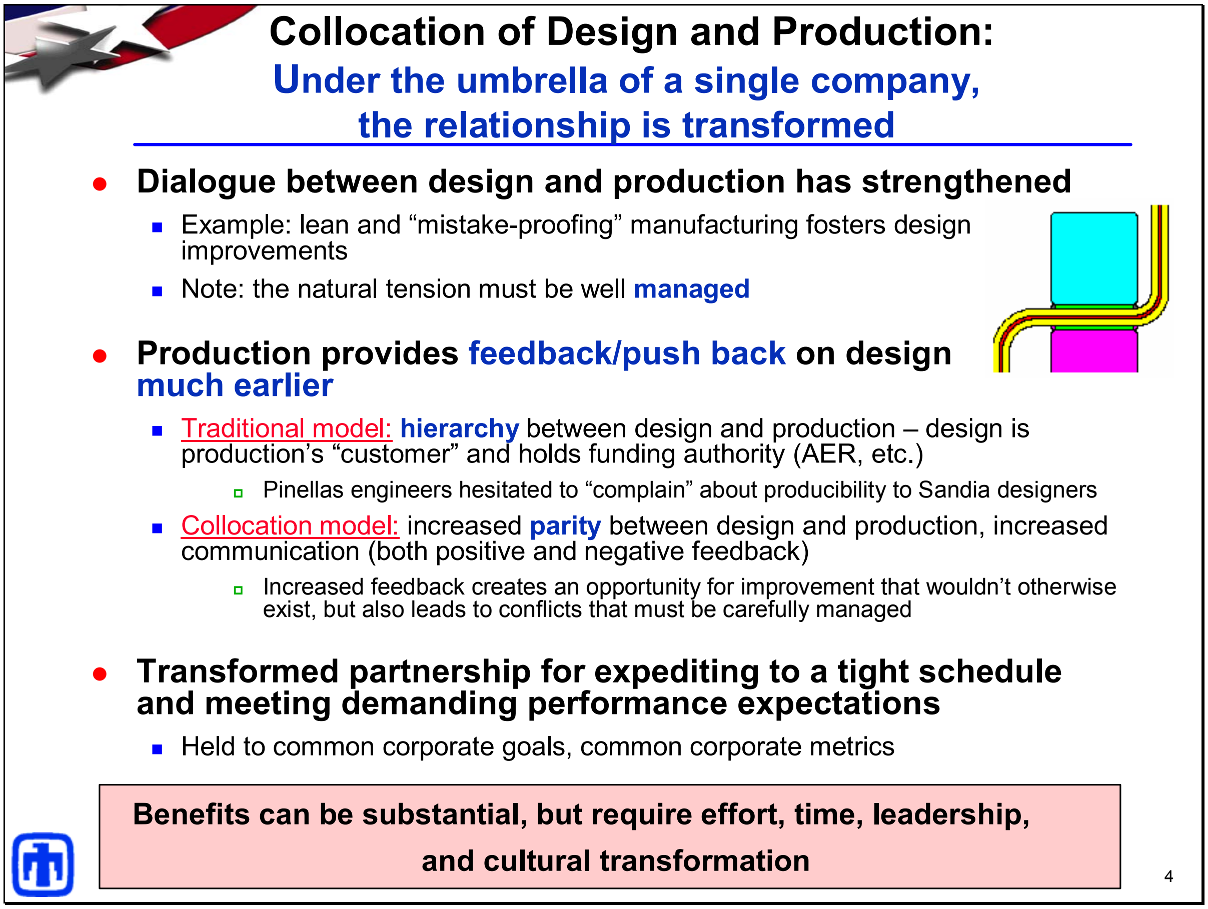
Pinellas "Then" vs. Sandia Today

Contrasting the neutron generator missions at Pinellas "then" and Sandia today requires a sense of context. In 1957, Pinellas received the NG mission from the GE Milwaukee Plant (which had manufactured small numbers of NGs in the mid-1950s), aiming for an initial capacity of ~600/year.[7] The first unit was shipped from Pinellas in January 1958; however, the yields during this time were abysmal.[8] In 1965, Pinellas produced its maximum yearly total of ~12,000 neutron generators.

[7]According to Addison Persons (GE Manager chosen for new NG plant), he chose St. Petersburg because he found the climate very favorable (from *Building the Bomb*, C.R. Loeber, Sandia National Laboratories, 2002).
[8]"During all of 1957 and into the third quarter of 1958, [Pinellas] made thousands of subassemblies and hundreds of final units, with practically 100 percent scrap…" –Addison Persons

Clearly, Pinellas encompassed a capacity that Sandia facilities were never designed to meet. When contrasting Pinellas in 1992 to Sandia today, one must be cognizant that Pinellas would have downsized its operations to align with the lower production requirements Sandia fulfills today. This discrepancy makes comparisons of Pinellas and Sandia costs per unit, floorspace per unit, or workers per unit problematic. Finally, it is important to note that the square footage numbers are net, rather than gross, values and the annual budget for Pinellas has been adjusted for inflation for comparison to the current Sandia annual budget numbers.



Transformation from Traditional to Collocation Model

Collocation of design and production was the primary factor differentiating options of transferring the NG mission to Sandia vs. Kansas City (costs were relatively comparable). The expected benefits of design/production collocation, coupled with major stockpile reductions (such as Presidential Nuclear Initiatives I/II and subsequent Bush/Yeltsin agreements), led DOE/AL to favor increased collocation in NNR.

Specific arguments for NG collocation in the *Nonnuclear Consolidation Plan (NCP)* focused on risk minimization, highlighting that 40 years of production experience at Pinellas had not overcome the significant technical challenges intrinsic to a product encompassing very high voltages over small distances.[9] In fact, the *NCP* argued that “there is more technical risk associated with [NG] product transfer than any other in the complex…Collocating the uniquely difficult task of manufacturing NGs with the primary design agency will significantly reduce that risk.” More detailed arguments were not elucidated in the *Nonnuclear Consolidation Plan* or the subsequent *Nonnuclear Consolidation Environmental Assessment (EA)*.[10] Indeed, the *Nonnuclear Consolidation EA* did not incorporate an alternative that sited neutron generator production anywhere other than Pinellas or Sandia.

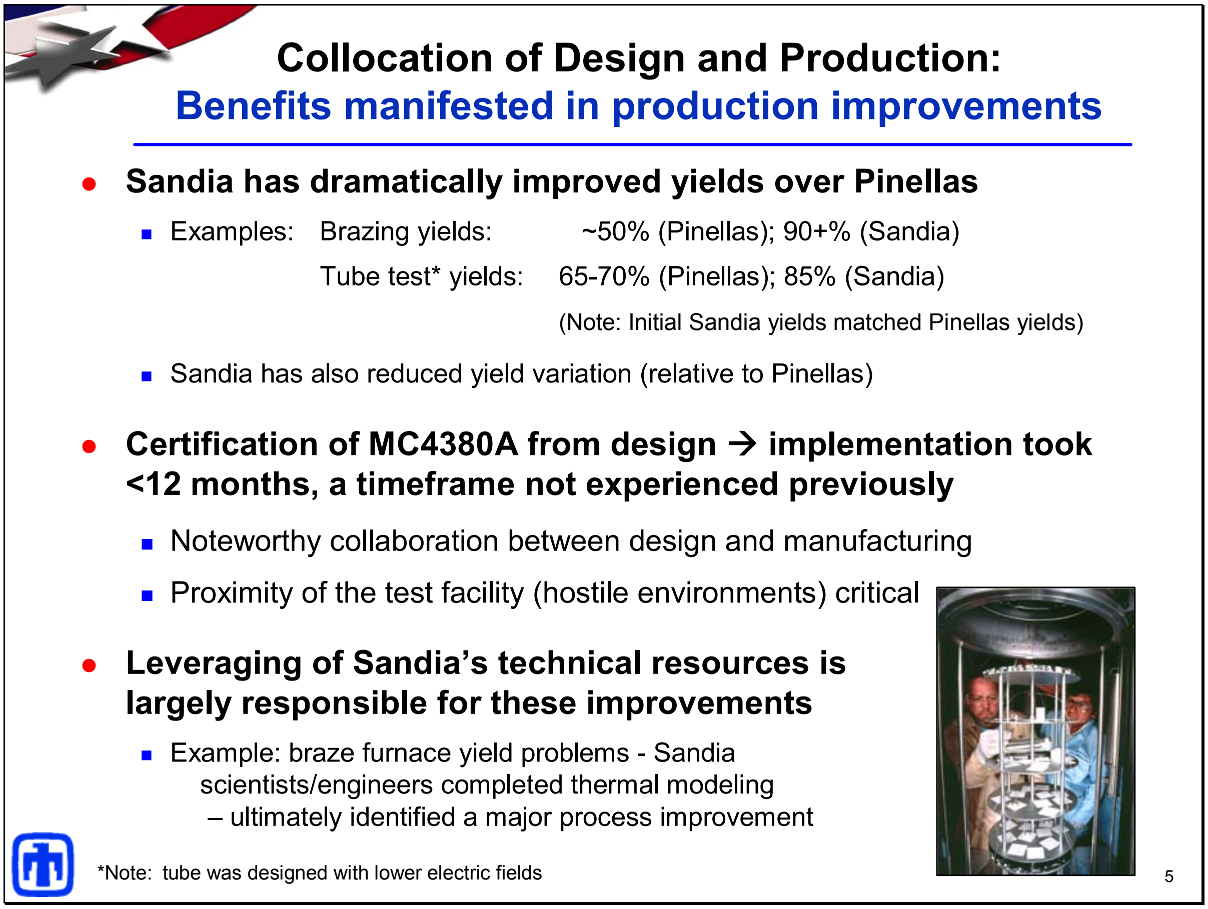
[9] *Nonnuclear Consolidation Plan*, March 20, 1992.
[10] *Nonnuclear Consolidation Environmental Assessment*, June 1993.

In hindsight, other benefits have been realized through collocation of production and design, largely due to the opportunities that emerge when all parties are working for the same company. These opportunities can be realized through willingness on both sides to accept change and a cultural shift from a traditional to a new model of interaction. In this new model of interaction, communication has been enhanced. This increased dialogue has heightened a healthy tension between design and production and allowed quicker feedback, decreasing the timescale for ascertaining whether designs are producible and allowing important manufacturing principles to impact design. However, the health and benefit of the tension relies upon sound leadership/management, as discussed below.

A primary reason communication (both positive/negative feedback) is enhanced is the restructuring of the relationship between design and production. In the traditional model, the design agency assumed the "customer" role for the production agency. For example, the production agency did not receive spending authority until the design agency released drawings specifying the design (e.g. AER - Advanced Engineering Release). On one hand, this made production very responsive to design's needs and put pressure on the design agency to freeze the design so parts/fixtures could be obtained and production schedules met. On the other hand, it created schedule risk, and the asymmetry in the relationship often translated to the production agency subjugating its needs, criticisms, or ideas for better design manufacturability to keep the "customer" happy. It is important to note design refinement for manufacturability did occur in the Sandia/Pinellas relationship.

In the "collocation" model, the hierarchy (and some of the traditional customer/supplier formality that helped implicitly define roles and responsibilities) may be replaced with a more equal partnership where production has more fiscal autonomy. At Sandia, this has allowed production to "push-back" in a manner production at Pinellas did not. Production has the authority to spend money on fixtures and parts prior to the AER, allowing the purchase of long lead-time items and tooling. However, this constrains the designers to parts and fixtures already procured. The increased push back that accompanies the collocation model (particularly in terms of increased communication by production that can understandably be perceived as a greater resistance to design decisions) creates new challenges in defining roles and responsibilities and a true partnership. The significant challenges the NG program has faced in these areas are discussed in later slides. It is important to note that collocation fosters, but does necessarily mandate, such a shift in hierarchy and in the traditional relationship between the production and design agency.

The collocation model also results in design and production personnel working towards common corporate metrics and goals, which can transform the ability of both to realize performance dividends. For example, with two companies, production might work towards a "production goal" of producing a percentage of the "design limit" (a value <100 percent, determined by the producibility of the design and considered outside the range of influence for the production company). With design and production working together, the "design limit" effectively disappears, with design and production working towards a more producible design and a singular production goal. The NG program has seen tangible improvements due to these benefits; specifics are discussed in the following slides.



Production Improvements

The production of neutron generators at Sandia has exhibited several tangible improvements over Pinellas. The collocation of design and production personnel has contributed to these improvements. First, the production yields, particularly brazing yields, have increased dramatically at Sandia. When the mission first came to Sandia, the initial yields for both brazing and tube tests were roughly the same as Pinellas' yields (after ~40 years of operation). The design of the MC4277 neutron tube with lower electric fields (as well as the new ion source design) has also contributed to tube test yield improvements.[11]

Sandia's technical resources, such as computer modeling, have had a major impact on process characterization, troubleshooting and subsequent improvements. Improvements in the braze furnace yields are an excellent example. The braze furnaces are a major bottleneck in the neutron tube production line. Thermal modeling of the furnaces and the placement of

[11] All the MC4277s prior to full production at Sandia were fabricated by technicians in a development environment (both at Sandia and Pinellas) without high voltage breakdown. However, Pinellas never produced the MC4277 in a production environment, so it is unknown if high voltage breakdown could have been avoided there.

parts being produced indicated that the production throughput of the furnaces could be substantially increased through modification of the primary heating modes, thermal capacity, and temperature-time profiles.

Second, the variation in yields has been significantly reduced at Sandia. For example, at Pinellas, the brazing yields averaged ~50 percent, but the yields varied widely (tens of percent) on either side of this average. At Sandia, the "plus/minus" on the yield average is much tighter, reflecting improved process consistency. In these cases, collocation of design and production, under a single contract, helped design engineers understand the impact of such dramatically low yields on the production organization, the design organization, and on Sandia as a whole. This further motivated the design organization to help identify solutions, including changes to product design when necessary.

Third, the implementation of new designs was demonstrated to be notably shorter than previous implementations with the certification of the MC4380A.[12] This substantial improvement can largely be attributed to improved communication, collaboration, and a common corporate goal. The hostile environments test facility is an important example where common company metrics and goals allowed prioritization and efficient use of a key facility, with the resulting decrease in overall turnaround time and, ultimately, certification time.

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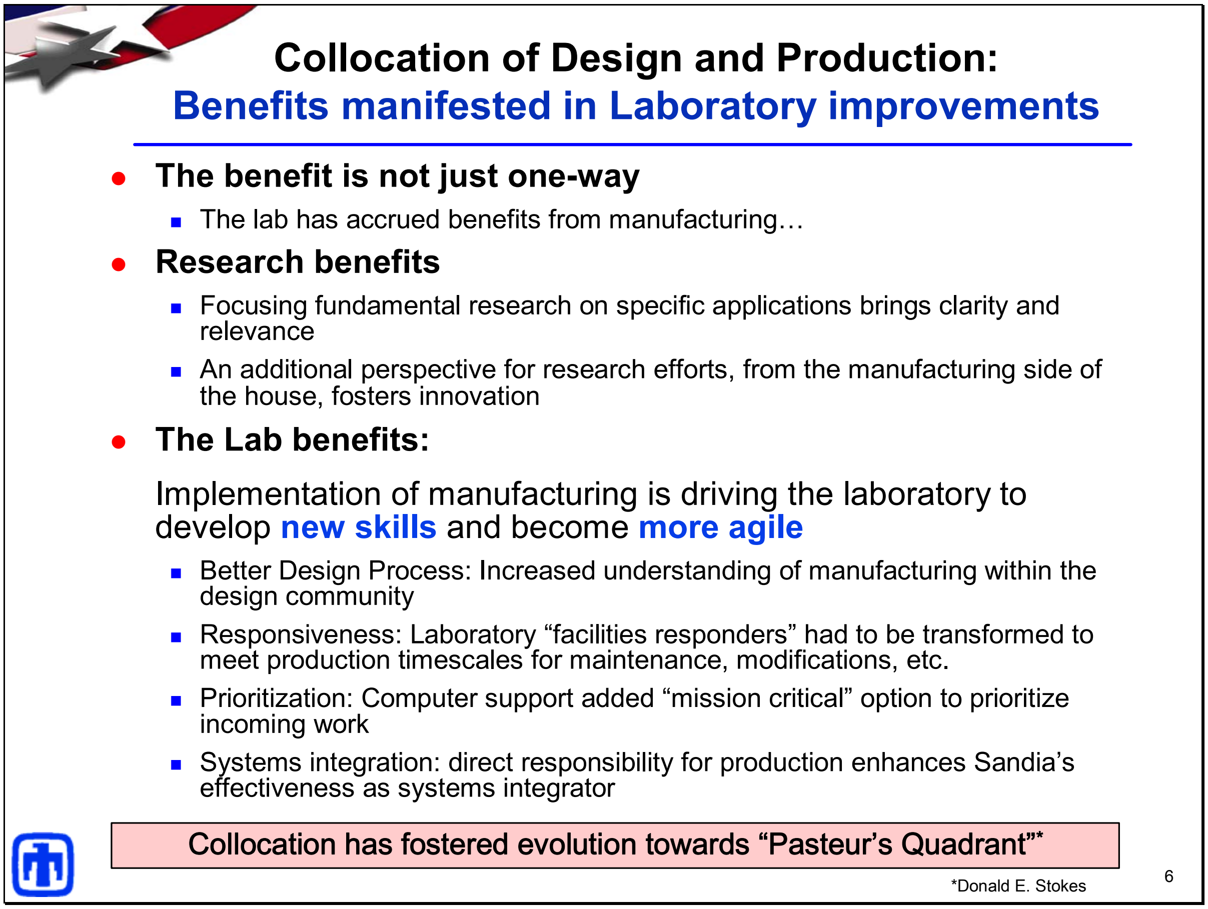
[12]This accelerated timeframe was noted prior to WR production in "Sandia Neutron Generator Production," a briefing by R.G. Spulak and T.M. Bomber, 1998.



Laboratory Improvements

While the benefits production accrues through collocation with design are rather intuitive, the NG mission transfer demonstrated tangible benefits to Sandia as a laboratory. In other words, though less obvious, the benefits of collocation flow from production to the broader laboratory as well. First, the character of research at Sandia has been enhanced by the addition of the NG production mission. Specifically, the production mission provides tangible applications for fundamental research.

To illustrate, first principles calculations and experimental measurements of helium-3 (generated from tritium occluded on NG targets) retained in the NG target lattice are examples where production influenced basic research in the broader laboratory, giving direct insights on the implications of the research. The retention or release of this helium-3 determines the increase in pressure in the neutron tube, which ultimately determines the life of the tube. First principles calculations and experimental measurements are a critical key to understanding and extending NG lifetimes, which has very significant implications to the DOE complex at large, as well as the DoD.

Donald Stokes, in his book, *Pasteur's Quadrant,* argues for a two-dimensional, rather than linear, connection between basic and applied research.[13] In his view, the vertical axis can be visualized as basic research, and the horizontal axis as applied. If the space between the axes is divided into quadrants, Pasteur's quadrant is the one that captures the essence of both basic and applied research, or what Stokes refers to as "use-inspired basic research" -- as exemplified by Louis Pasteur's stunning achievements from both practical and theoretical standpoints. In this sense, collocation has helped Sandia evolve towards Pasteur's quadrant through such inspiration.

It is important to note, in both the traditional and collocation models, the NG design organization has ultimate responsibility for neutron tube design and performance, including assimilating new research results into design. While the change in model does not alter this responsibility, it does expand the perspectives, and sometimes funding sources, impacting the NG-related research at Sandia. In the traditional model, the production agency had little interface with basic research at the national laboratory. In the collocation model, production has an opportunity to contribute an additional perspective for research efforts – for example, in the helium-3 problem discussed above, how films are grown and how manufacturing processes affect the ability of the lattice to retain helium. While the roles and responsibilities of design and production in greater laboratory research continue to evolve, a strong spirit of collaboration and a willingness to adapt to a new business strategy have facilitated the change from a traditional to a collocation model, helping to reduce the natural conflict arising from such a large cultural shift.

Second, housing production within Sandia has challenged the laboratory to extend and enhance its suite of skills, particularly in the responsiveness and agility of its infrastructure support. For example, the NG production mission required response from "facilities" (i.e. the organization tasked with responding to physical infrastructure requests) with far shorter turnaround times than other traditional laboratory missions, because the impact of downtime on production is quite different from the impact on design/R&D.

Today, NG production expects and attains turnaround times as short as a day from Sandia's "facilities" group. Computer support adapting its response to fit production timescales is another example of a positive impact of production on the laboratory as a whole. In both of these examples, it is clear that the NG mission has forced the laboratory to create clear mechanisms for prioritization – which has benefits not just for production, but for all mission- and time-critical work at the laboratory.

Third, the laboratory has gained the largely unquantifiable, but nonetheless critically important, benefit of insight into the production arena. The cross-talk and dialogue between production and design has cultivated a more integrated, complete understanding of production in designers, improving the design process. This understanding is also critical to Sandia's effectiveness as the systems integrator.

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[13]Stokes, D. E., *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press: 1997.

Collocation of Design and Production:
Applying Lessons Learned to Future Collocations

- **Do not underestimate the effect of cultural differences on collocating design and production**
  - For the NG mission transfer, cultural challenges were greater than expected
  - Evaluations for other mission transfers should not discount the **site-specific** culture that could derail the benefits of collocation
- **"Divvying" up production among different laboratories increases risk and cost**
  - Neutron tube target loading (NTTL) was sited at LANL
    - Had to solve all the relocation issues at multiple sites
    - Mission split incurs unnecessary transportation, cost and risk
    - LANL budget for NTTL: $7M/year
    - Sandia's estimate for adding the NTTL mission: ~$1.5M/year
- **Collocating design/production by building an autonomous production facility <u>near</u> a design facility is not cost effective**
  - A Conceptual Design Report was developed for construction of a stand-alone facility at SNL – ended up having a >2X price tag
  - Not cost effective - because doesn't effectively leverage existing overhead at receiver site

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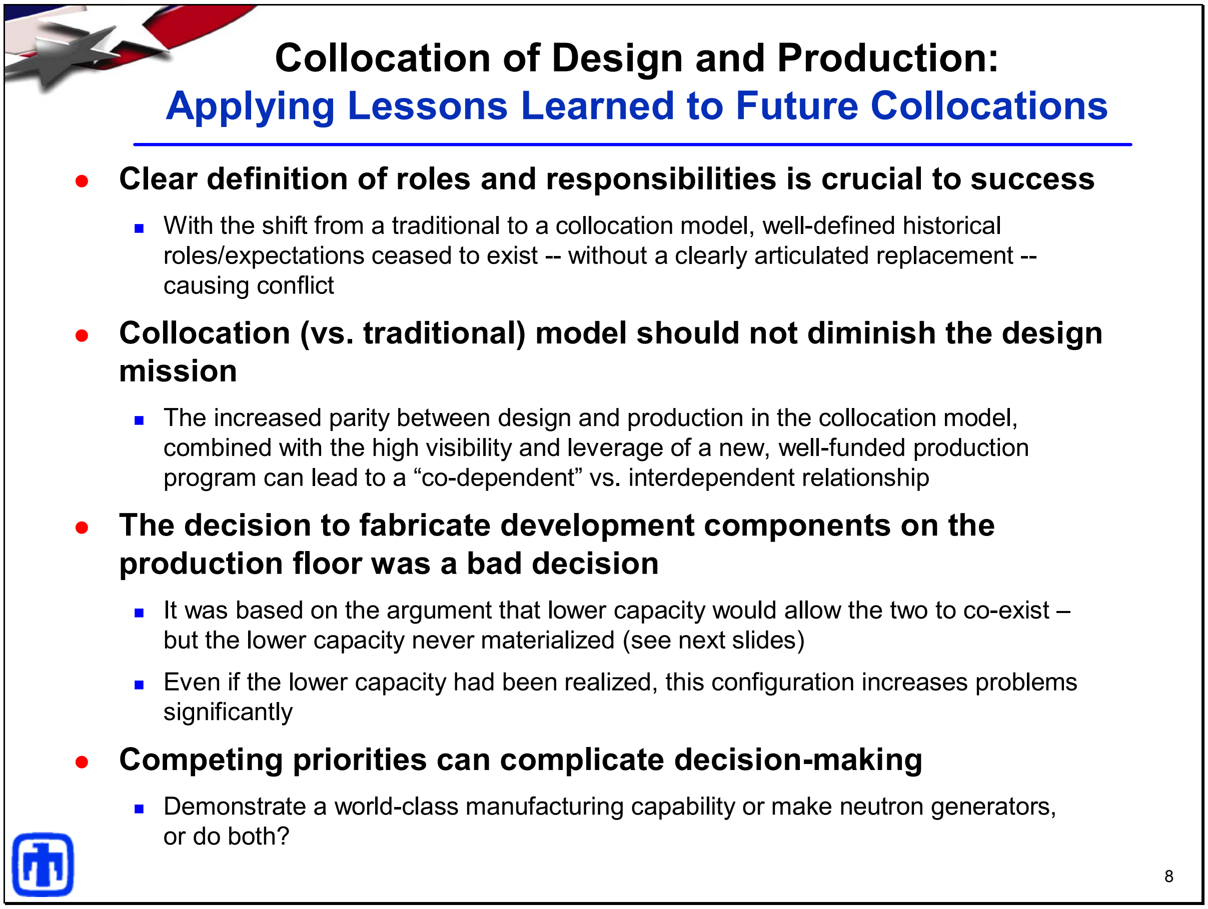
Lessons Learned

While the collocation of NG design and production has ultimately yielded benefits for both production and design, the evolution has taken time and effort. In particular, a recognition of the cultural differences between design and production personnel has been key to the transition, but the challenge was more formidable than anticipated. Incorporation of Pinellas personnel into the transition process, as well as hiring from the local industrial base (see page 30), helped raise visibility of differing perspectives. Commitment by design and production personnel to collaboration and interpersonal respect has been critical to resolving many conflicts that have arisen. Nonetheless, cultural forces are easily underestimated and can be quite challenging, particularly as expectations surrounding roles and responsibilities are forced to change from traditional models. This is an important lesson for all future collocations of design and production.

Another important 20/20 hindsight: siting the neutron tube target loading mission separately from the NG production mission incurred additional risk, complications, and costs. The original decision to site target loading separately at Los Alamos was primarily based on the need to meet the NNR schedule. At the time, the incorporation of target loading at Sandia would have required an Environmental Impact Statement (vs. the Environmental Assessment completed for NNR), which would have taken too long to meet the NNR schedule. An experiment, demonstrating that neutron tubes with targets loaded at Pinellas and Sandia California (representing off-site loading by a site not experienced in this process) showed similar neutron outputs, verified that remote target loading was feasible and allowed the mission to be assigned to Los Alamos with greater technical confidence. In retrospect, while remote target loading was feasible, an assessment of the additional transportation, costs, and increased risks (coupled with the "double" relocation costs if target loading were ultimately moved to Sandia – as it may be in the near future) might have effected a different outcome. The lesson learned: planning for future mission transfers should incorporate a healthy wariness of splitting missions between sites.

In evaluating options for collocating design and production, a conceptual design report was prepared for a NG production facility physically located at Sandia, but operating as a stand-alone entity (i.e. not sharing any of Sandia's infrastructure – security, medical, etc.). In a sense, it was akin to a smaller Pinellas, relocated to Albuquerque. This option was extremely costly because it did not leverage the overhead at the receiver site (which, after all, was the fundamental cost basis for consolidation through NNR). In addition, it is arguable whether many of the benefits discussed in the previous three slides would have truly been realized had production and design not been under the umbrella of a single company.



Lessons Learned

The traditional design agency/production agency model provided clear roles based on a customer/supplier framework. Without a doubt, the collocation model disrupted those roles, and, unfortunately, replacement roles and responsibilities were not defined from the outset, but allowed to evolve. Naturally, conflicts arose (and continue to arise) as the boundaries for areas previously “within the territory” of one side or the other became more ambiguous. Compromises, necessary to resolve the conflict and implicit in movement from a hierarchical framework to a level partnership, are a difficult, but expected, outcome of the model change. Nonetheless, anticipating and planning for such conflicts and compromises by clearly delineating roles and responsibilities go a long way towards minimizing or eliminating such conflict before it becomes disruptive.

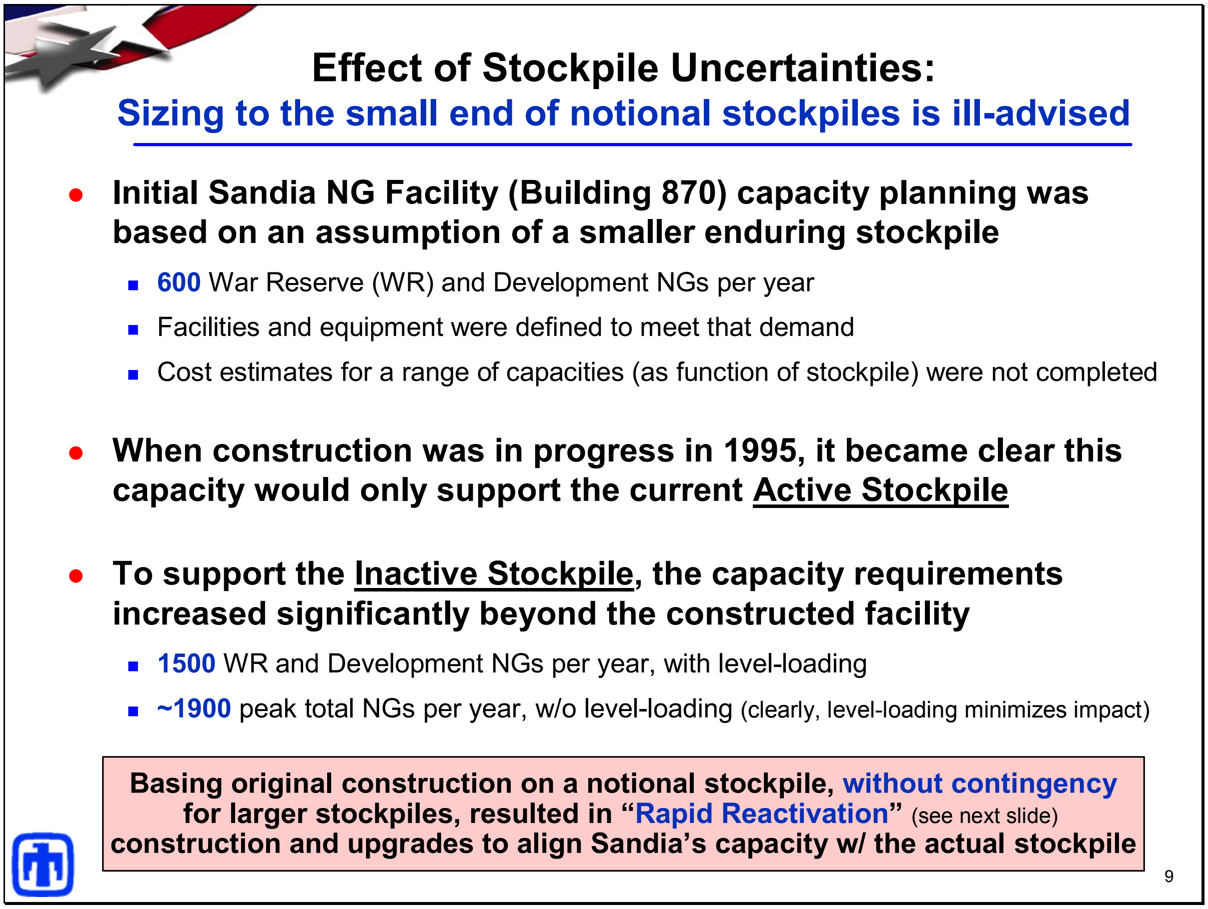
Several issues independent from consolidation impacted NG design at Sandia during the time of Nonnuclear Reconfiguration (for example, the closure of the development laboratory for explosive NG testing).[14] These factors contributed to a diminished Sandia NG design

[14]Nonnuclear Reconfiguration provided the funds to expand the 905-construction project to add facilities for testing of WR neutron generators. NNR did not drive the closure of the development laboratory for testing explosive NGs. The expansion of Building 700, completed ~18 months ago, to add development space for NGs was funded through GPP.

capability in the same time period when Sandia NG production was receiving significant effort, visibility, and funding. As a result, one viewpoint is that a somewhat "co-dependent" relationship between design and production formed. In other words, design was not in a healthy state, and production "enabled" design's illness by funding some areas that were traditionally well within design's space. The opposing viewpoint is that the more ambiguous boundaries between production and design and the new model of partnership allowed a new perspective and new resources to be applied to the design process. Regardless of the perspective, the importance of maintaining a healthy design function in concert with a collocated production mission can not be overstated.

The decision to fabricate development components on the production floor was driven by an anticipation of lower capacity requirements, which would allow the two to co-exist on the same floor with the same equipment. Ultimately, the efficacy of this theory would never be tested, because the higher capacity numbers of "Rapid Reactivation" (see the next four pages) resulted in separation of these functions. In hindsight, even if the capacity had remained at 600 units/year (see next slide), putting production and manufacturing in the same space was not the best option. For example, one could envision a reluctance to modify well-qualified, in-control production processes and tooling to complete development work. Unfortunately, decommissioning of the neutron tube development laboratory was part of the proposed approach for "co-existence" of development and production. The funds to remedy this problem through acquisition of equipment and the modification of Building 700 to support development came from a combination of production funds and a special capital equipment allocation from the NNSA.

Finally, the competing priorities intrinsic to collocation of important missions can create multiple goals that may or may not be aligned. For example, there was a perception of confusion whether the goal was to make neutron generators or demonstrate a world-class manufacturing capability. Aligning these goals to accomplish both was a challenge that impacted decisions already complicated by logistical and political realities. Several of these decisions and their implications are discussed in the Consolidation Section of the briefing



Lessons Learned

Today, many predict decreasing stockpiles even beyond the Treaty of Moscow (2012) timeframe. These projections, whether they prove speculative or prescient, nonetheless have precipitated Congressional interest in aligning the DOE complex infrastructure with smaller future stockpiles (as evidenced by the request for the Nuclear Weapons Complex Infrastructure Task Force referenced earlier). The experience with NG relocation provides some important lessons learned when attempting to align construction with estimates for the future.

At the outset, planning for the Sandia Neutron Generator Facility (NGF) was based on predictions for smaller future stockpiles. This translated into a capacity requirement for the NGF of ~500 WR NGs/year and ~100 development NGs/year, for a total of 600 NGs/year. Construction of the facility and incorporated equipment were based on this capacity, without contingency for larger potential stockpiles. However, during construction in 1995, it became clear that a START I-like stockpile would have to be supported, including the inactive stockpile. Unfortunately, the capacity of the in-progress NGF could only support the active portion of the then-current stockpile.

In order to support the active and inactive stockpile, the capacity requirements rose to ~1300 WR NGs/year and ~200 development NGs/year (note: the initial estimates for 100 development units for the smaller stockpile had been too low), for a total of 1500 NGs/year, with level-loading. Those estimates rose as high as ~1900 peak total (WR and development), if level-loading was not employed (giving an indication of its importance). Because contingency in the neutron tube and generator production lines had not been incorporated, the facility and equipment, as planned, could not accommodate the higher requirements without significant modifications (discussed on the next page).

In hindsight, this example illustrates that sizing to notional future stockpiles can prove unwise, particularly if the choice is made to size to the small end of the range, without contingency for larger sizes. Indeed, the modular approach used to assess the sensitivity of capital costs to varying stockpile sizes in the Complex-21 study demonstrated that costs can increase significantly if both facility and equipment modules must be added to support higher stockpiles. On the other hand, the Complex-21 study also showed that facilities sized to provide contingency for higher stockpiles, with equipment sized to smaller projected stockpiles, can meaningfully reduce costs if higher stockpiles ultimately persist.

Effect of Stockpile Uncertainties:

Rapid Reactivation lesson: add contingency capacity to original construction, if sizing to notional stockpile

- **Rapid Reactivation Question:**
  - Could the complex rapidly reactivate a system from the Inactive Stockpile?
- **The answer for NGs (Building 870) was:**
  - Facility too small
    - Development/production could no longer share common space and equipment
  - Insufficient equipment to meet higher demand
  - Insufficient number of operators
- **Rapid Reactivation Construction/Mods:**
  - Building 857B was constructed for additional Neutron Generator fabrication
  - Extensive modifications were made to Building 870
  - ~$16 million in overall construction
  - Project began February 1999 and was completed January 2002
  - Facility modification and production occurred simultaneously in same space with concomitant increased risk to product

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Rapid Reactivation

The name that has come to describe the retrofit of the Sandia NGF to higher capacity, “Rapid Reactivation,” resulted from the broader question of whether the complex could rapidly reactivate a system from the inactive stockpile. Clearly, the NGF, as initially planned, only supported the active stockpile and did not have the capacity to “rapidly reactivate.” The facility was simply too small and did not have sufficient equipment or operators.

As a result, a Baseline Change Proposal to the NNR Project was submitted requesting modifications to Building 870 and additional equipment prior to WR qualification activities, while the impact could still be minimized. Because this request was denied and Rapid Reactivation did not receive authorization to proceed until February 1999 (after publishing a separate Environmental Assessment and receiving a Finding of No Significant Impact), the upgrades had to be implemented in parallel with WR production.

These upgrades were significant and directly impacted WR production. The Building 870 neutron tube line was modified to increase its capacity (changes in the East Annex were particularly troublesome). Building 857B, a separate facility, was constructed to accommodate NG fabrication and the NG production line. Fortunately, intense planning and responsiveness by both the construction and production sides of the house enabled production to maintain yields throughout construction. However, having ongoing construction in the midst of WR production without negative impacts to yield should not be considered the norm (for example, at Pinellas, yields inevitably fell in concert with facility modifications).

In retrospect, advance planning, through either a facility designed with contingency capacity or a plan to implement a “Rapid Reactivation” type solution prior to commencement of WR qualification activities, could have saved dollars and effort and meaningfully mitigated risk. In other words, if the choice is made to design to a smaller, notional stockpile, it is prudent to acknowledge the uncertainty and risk and implement measures to allay future costs and complications.

Consolidation: Savings resulted from reductions in overhead from Pinellas *closure*

- **Pinellas: estimate the fraction of overhead for NG mission at ~50%**
  - ~$34M/year ($FY92) overhead saved w/ closure
- **Sandia: estimate amount overhead increased due to absorption of NG mission**
  - ~$4-5M/year ($FY04) overhead increase
    - ~$2.1M – utilities, maintenance
    - ~$2+M – management, purchasing, other...
  - Since the overall Sandia mission increased <~3%, wouldn't anticipate a significant change in most overhead functions in the Table →
  - Note: Transfer of **nuclear** missions (or significant increases in overall mission) will not see the same negligible increase in overhead at the receiver site
    - Further study is needed
    - Case-by-case study could be required

Pinellas Plant Annual Overhead as estimated in *Nonnuclear Reconfiguration Cost Effectiveness Report*, January 1993

Environmental	$3.3M	4.6%
Waste Management	$1.4M	2%
Health	$1.7M	2.4%
Safety	$2.6M	3.7%
Safeguard/Security	$5.0M	7%
Plant Engineering	$3.4M	4.8%
Utilities	$3.3M	4.6%
Maintenance	$16.4M	23.1%
Management and Administration	$33.7M	47.5%
Emergency Ops	$0.2M	0.3%
TOTAL	$71M	

Re-locating NG production without closing Pinellas would not have resulted in similar savings, since substantial Pinellas overhead would have remained.
Total savings from closing Pinellas are approximately double those for NGs alone

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Overhead Savings and Increases

The dominance of fixed costs (i.e. overhead) at DOE weapons sites was clearly articulated in the *Phase 1 Report of the Privatization Planning Panel*, as was the cost-saving that could be realized by reducing the number of sites (and therefore, the fixed costs). In essence, the overhead cost savings from consolidation could not be discounted; these savings ultimately drove Nonnuclear Reconfiguration, despite political opposition.

For Pinellas, the *Phase 1 Report of the Privatization Panel* estimated the total overhead to be ~$66M based on the FY1992 Production and Surveillance budget. The *Nonnuclear Reconfiguration Cost Effectiveness Report* estimated the overhead to be ~$71M (FY93) based on the "FY1993 approved funding program for the involved sites."[15] These numbers are relatively consistent with Pinellas' indirect spending figures (~$68M FY1992) for that timeframe. In FY1992 NGs comprised roughly half of Pinellas' overall mission; for simplicity, we have attributed ~50 percent of these costs to the NG mission. These dollars (~$34M FY1992) can be considered the gross NG overhead savings from closing Pinellas.

[15] *Nonnuclear Reconfiguration Cost Effectiveness Report*, January 1993.

These savings must then be contrasted with the increased fixed costs at the receiver site (Sandia) due to the absorption of the NG mission. In FY2004 dollars, we estimate that the addition of the NG program at Sandia leads to an increase of ~$2.1M/year in utilities and maintenance, plus a few million dollars more in other overhead (purchasing, management, etc.). Given the size of the NG mission relative to Sandia's overall mission (<~3%), we judge it unlikely that other overhead functions (such as health, safety, security, legal, library, etc.) added FTEs as a result of the NG mission absorption. Interestingly, after independently estimating this ~$4-5M/year increase, we found that one of the three outside consultants at the time of decision-making on NNR (K. Woodfin) estimated the increased overhead at a receiver laboratory site to be $4.4M/year.[6]

In contrast, the increased fixed costs at a receiver site for a significantly larger nuclear production mission could be much more significant than those experienced at Sandia for absorption of the relatively small NG mission. Furthermore, the magnitude of the absorbed mission, relative to the overall mission at the receiver site, would be a significant variable in determining the "absorption overhead" increase. If the increase approached the magnitude of the overhead savings at the site to be closed, arguments for consolidation based on cost would not be as compelling as those exhibited for Nonnuclear Reconfiguration.

Finally, we reinforce that the primary savings from NG relocation came from closure of Pinellas and the elimination of the facility overhead. If the NG mission had been transferred to Sandia, but the other Pinellas production missions retained at Pinellas, a great portion of these fixed costs would have persisted. Additionally, we note that the total savings from closing Pinellas roughly double those indicated here, due to the other missions (besides neutron generators) that previously resided there and were transferred to other sites as part of NNR.

Consolidation:
NG mission transfer yielded <5 year payback time

- **Conservative estimate of payback time*** **~4.7 years**
  - Approx. Pinellas → Sandia **one-time** transition costs **~$137M**
  - Approx. annual (Pinellas overhead savings)-(Sandia increase) **~$29M/year**
- **Must also keep in mind…**
  - **Dollars would have been spent upgrading Pinellas…**
    - When making decisions on mission consolidations, some mechanism should account for the cost that would have been incurred upgrading aging facilities and equipment
    - Ex. Pinellas would have needed upgrading to a CAT 3 Nuclear Facility
  - **…and not just the portion of the capacity Sandia replaced**
    - When downsizing through transfer to a new site with smaller capacity, you are essentially only "upgrading" a portion of the original donor site's capacity and minimizing future upgrade costs
  - **Dramatic decrease in inventory and work in process (Pinellas carried 1-2 years in material) have resulted in lower carrying costs at Sandia**

*Note: It is tempting to compare annual program costs (direct and indirect) or cost per unit at the two sites to calculate these savings. However, it is our judgment that (1) program costs do not capture the overhead savings of closing the doors, (2) the NG missions at Sandia/Pinellas function as capability-based capacities, (3) comparisons to Pinellas of yesterday do not account for layoffs/downsizing that Pinellas would have completed for today's stockpile/capacity, (4) reduced volume at Pinellas would have increased unit costs.

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Payback Period

The cost studies for NNR focused heavily on the payback time for consolidation – the number of years of savings required to pay for the one-time transition costs. In hindsight, we can estimate the actual payback period for the NG mission (using the standard definition, which neglects the time value of money) by simply dividing the approximate one-time transition costs by the approximate annual savings. The estimated $137M transition costs include the DOE dollars ($131M) spent for reconfiguration (construction, recertification, infrastructure, etc.) and a $6M military interagency transfer. However, this amount does not include neutron generator dollars that would have been spent regardless of NNR (prototyping, design support, etc.).

To approximate the net overhead savings, the numbers on the previous slide can be used to yield a conservative estimate, because the Pinellas savings ($34M) are in FY1992 dollars and the Sandia costs ($5M) are in FY2004 dollars. Thus, using the simple definition above, the payback period was less than five years. An alternative calculation, utilizing the Internal Rate of Return (which does account for the time value of money), yielded a similar timeframe of 4-5 years (see Appendix A).

Payback period calculations taking credit for overhead savings are valuable in gaining a high-level sense of the ultimate cost/benefit/payoff of the NG mission transfer, but fail to capture certain costs, particularly those that were ultimately avoided. For example, accounting only for the cost savings due to the closure of Pinellas neglects the fact that Pinellas would have required dollars for upgrades (for example, Pinellas required an upgrade to meet the definition of a CAT 3 Nuclear Facility). Furthermore, those dollars would have upgraded Pinellas as a whole (not just the portion Sandia replaced). In addition, Sandia has dramatically reduced the inventory and work in process that contributes significantly to overall costs (see Appendix B).

It is important to understand the difference between these calculations based on overhead and a comparison of changes in annual costs. In other words, the ~$20M (FY04) difference (see page 10) in annual program costs between Pinellas and Sandia could ostensibly be viewed as the savings from the mission transfer. Such an analysis fails to capture several important factors. First, the downsizing that would have occurred to align Pinellas to the requirements Sandia meets today is not captured in the ~$20M difference. Secondly, from capability-based capacity arguments, it is intuitively clear that the unit cost would have increased at Pinellas as its capacity decreased. However, any quantification of the degree would be purely speculative. Finally, the central cost factor for consolidation was reduction in overhead costs; comparing changes in program costs simply does not capture the savings of closing the doors at Pinellas.

Consolidation: Lessons Learned

Workforce planning will make or break the process

- **Retaining/developing the right suite of workers is critical**
  - The importance of advance planning cannot be overstated
  - Sandia and Pinellas compiled a list of critical skills and brought 84 workers over -- an essential step
    - Key transfers included: an experienced materials management/planning manager and the Pinellas technicians involved in the relevant development work for the design that was to be WR qualified at Sandia
  - Sandia hired additional personnel from the local industrial base
- **Labor relations should not be overlooked**
  - An adversarial labor environment could have had a large impact on the NG transfer
- **The importance of the timing of the announcement a plant is to be closed should not be underestimated**
  - Knowledge walks out the door, and the best leave first

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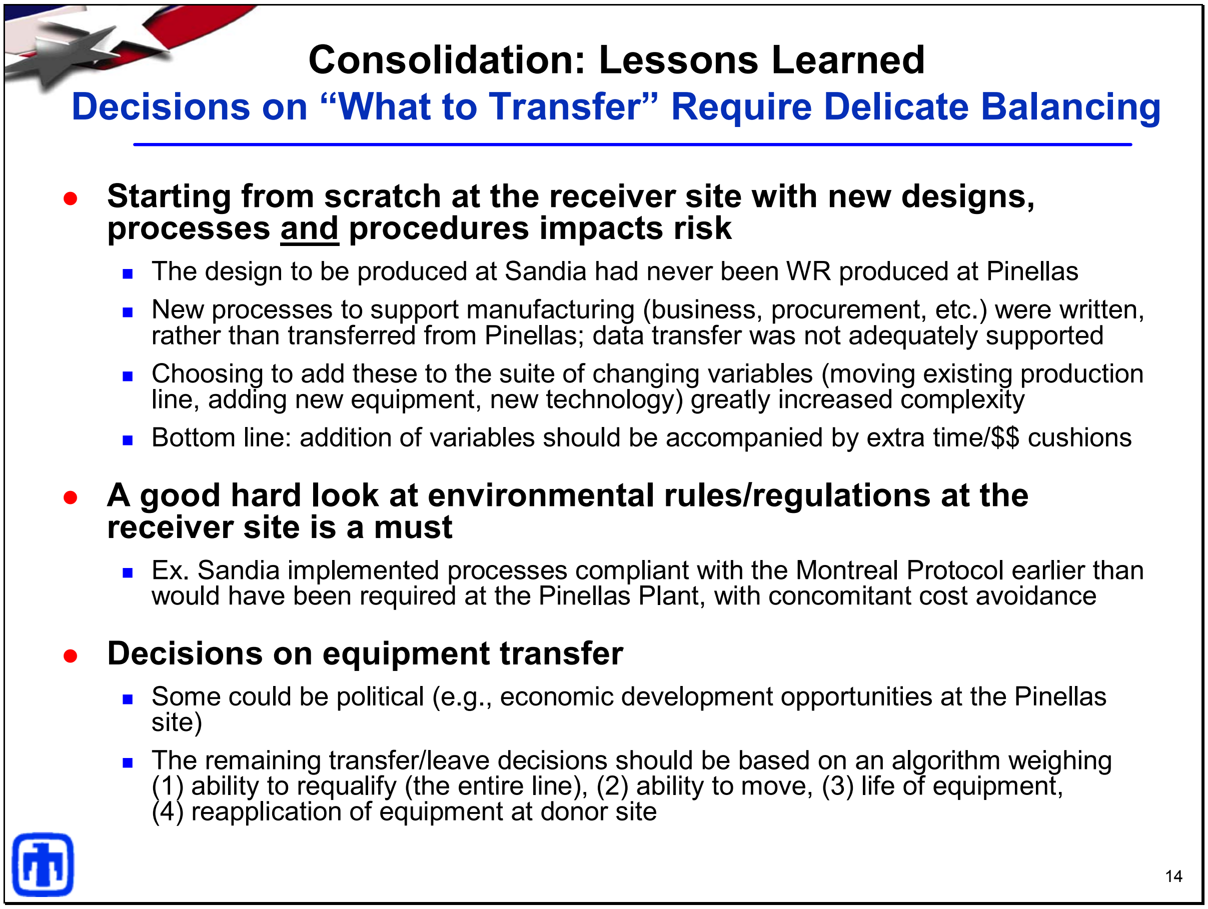
Workforce Planning

Though it seems obvious, planning is essential to achieving an effective and well-balanced workforce at the consolidation receiver site. Acknowledging gaps in the receiver site's personnel base is the first step. For Sandia, this acknowledgement allowed an assessment that led to the transfer of 84 workers from Pinellas, with some transferring early in the NNR timeframe.

These workers proved absolutely critical to standing up production at Sandia. The transfer of workers who were specifically involved in development of the MC4277 tube (which Pinellas had not produced as WR) was particularly important. However, without this advance planning, Sandia might not have been able to attract the highest quality workers – as those are the workers who would be most rapidly sought after for other jobs.

In addition, Sandia hired personnel from the local industrial base. These workers, along with the Pinellas workers, provided unique insight into production, both from a technical as well as a cultural standpoint. They vocalized viewpoints not generally indigenous to Sandia's culture, allowing impacts difficult to quantify, but important nonetheless. Finally and fortunately, the labor environment surrounding the NG mission transfer was not adversarial. While Pinellas' production floor operators had not been union, the operators at Sandia are part of the union. Because labor relations can be complicated and potentially litigious (with associated timescales), such issues should be considered thoroughly in consolidation planning.

Orchestrating the timing, skill balance, and logistics of the workforce, particularly a production workforce at a laboratory, requires detailed planning and an openness to acknowledging critical gaps at the receiver site. However, Sandia's experience indicates that this is time and effort extremely well-spent.



Transfer Decisions

Inevitably, decisions on what to transfer to the receiver site from the site being closed are impacted by numerous variables. For equipment, the needs of the site being closed must be taken into account. For Pinellas, Nonnuclear Reconfiguration made a tremendous effort to make the closure as "humane" as possible.[16] For example, certain equipment originally slated to be transferred to Sandia, but found critical to the transition of Pinellas to the private sector, was left behind. As a result, new equipment had to be purchased for Sandia.

Logistical and practical constraints also play an important role in decisions on equipment transfers. If equipment is quite onerous to move or near end-of-life, it may not be economically beneficial to transfer. In addition, the incorporation of used equipment, particularly equipment without complete records (maintenance, repair, etc.) can impact the ability and/or time to requalify a line. Of note, an important element of the Pinellas to Sandia transfer was the continuity maintained between disconnection of equipment at Pinellas and installation at Sandia. The same subject matter expert oversaw both processes (even though there was sometimes a gap of up to 18 months) for each piece of equipment.

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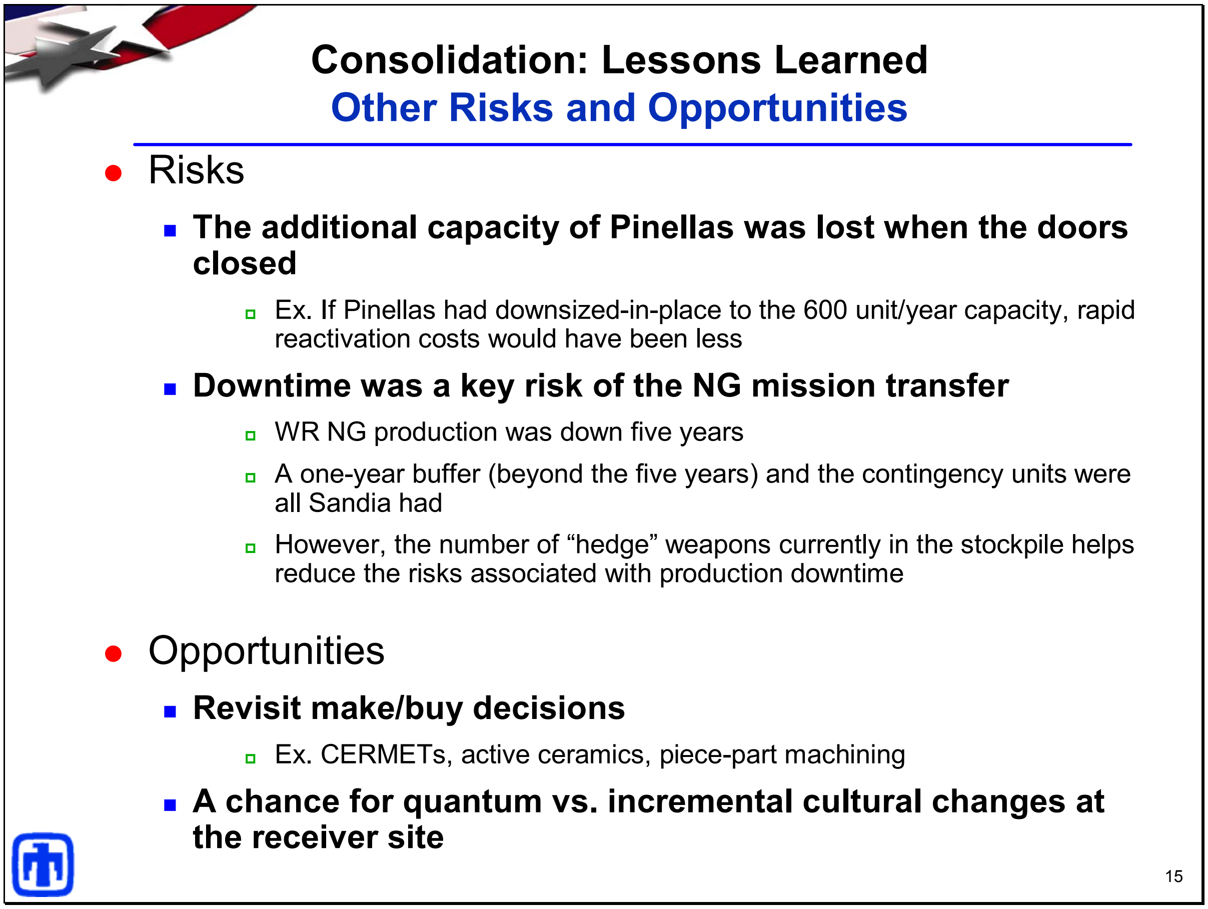
[16]Chuck Loeber, personal communication.

Comprehensive data transfer from donor to receiver site is a critical element of mission transfer. The transfer of Pinellas neutron generator and tube database capabilities employing VAX technology to Sandia, which was to be completed through an upgrade to modern databases using modern technology, did not receive the support needed. As a result, Sandia is only now approaching the capabilities Pinellas utilized. Not having readily accessible data, including Sandia production data, has hampered the solution to both design and production problems.

In addition to equipment, decisions must be made to determine which procedures and processes to transfer from the donor site. For NGs, Sandia created new administrative processes to support manufacturing, rather than transferring them from Pinellas. In addition, Sandia made the decision to manufacture a design that had never been WR produced at Pinellas. These decisions were generally outside industry norms, where it is expected that changes will be minimized during start up of production at a new location to aid troubleshooting efforts (by reducing the number of variables subject to change). If such decisions are made, time and cost cushions are advisable. An additional lesson learned from NG transfer – having the foresight and wherewithal to meet environmental regulations at the receiver site at the time of transfer can save headaches and costs later on (and is worth the up-front effort).

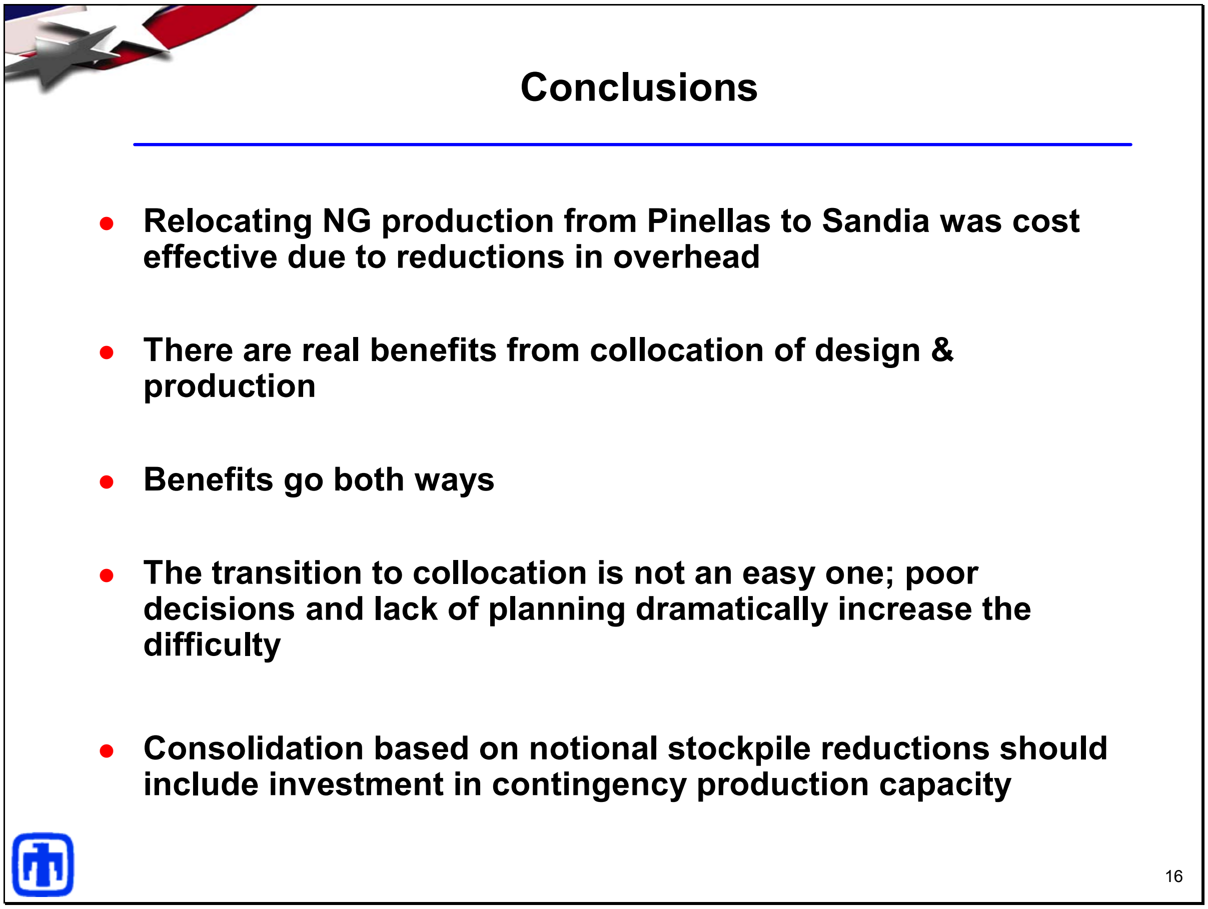


Other Risks and Opportunities

The NG mission transfer highlighted a few other key risks and opportunities. First and foremost, the Nonnuclear Reconfiguration schedule allowed five years of downtime for NG production within the complex. In other words, the complex was not able to manufacture NGs during this time period. The contingency units prebuilt at Pinellas, along with a one-year buffer (beyond the five years) before NGs would start “going red” in the stockpile, contributed to risk mitigation. Additional risk mitigation is present today in the form of “hedge” weapons; these weapons could contribute as additional contingency units, if the necessity arose due to a gap in production.

Secondly, the inherent surge capacity of Pinellas is simply not a part of the reconstituted capability at Sandia. If the need for such surge capacity were required, a Pinellas operating at Sandia’s current capacity would be much better positioned to meet that surge. In a sense, it provides the large-sized facility, smaller-sized equipment paradigm that meaningfully reduces risk if higher stockpiles come to be (discussed in the Effect of Stockpile Uncertainties sections). For the NG mission, this argument alone was not compelling enough to derail the NNR process.

Thirdly, the quantum (vs. evolutionary) nature of closing a site and transferring a mission to an existing or new site yields an opportunity for rapid step changes. These types of changes stand in contrast to the incremental, evolutionary changes usually accessible with an existing mission at an existing site. Rather, the receiver site is forced, through acceptance of a new mission, new facilities and equipment, and new people, to change profoundly. While a challenge, this is also an opportunity, particularly in the area of cultural change. It is also a chance to revisit and review current precedents – such as make/buy decisions – and get a current, fresh start.



Conclusions

Clearly, we have learned much from the transfer of the NG mission from Pinellas to Sandia. However, there are five major points that summarize the most important "20/20 hindsights." First, "shutting the doors" at Pinellas resulted in significant annual overhead savings. Because of the size and nature of the NG mission (relative to Sandia's overall mission), the increase in overhead at Sandia (that could have cancelled out such savings) was small – leading to an overall net savings. This was the main cost argument for Nonnuclear Reconfiguration as a whole, and it translated to the NG mission reconfiguration specifically. However, we caution that future consolidation decisions will require site-specific and production-specific mission analyses (to account for size/type of mission transfer, alleviation of upgrades at donor site, downtime, required surge capacity, etc.).

Secondly, collocating NG production and design at Sandia has yielded measurable NG production performance and schedule dividends. Through application of R&D, more manufacturable designs, and production improvements, production efficiency has improved and yields have increased relative to Pinellas. Collaboration of design and production to meet common corporate goals and metrics has also played a major role in improving performance.

Thirdly, Sandia has benefited as a laboratory from the collocation of NG production. Production has forced major elements of laboratory infrastructure, including facilities and computer support, to become more agile and responsive to production needs and timescales. Furthermore, the housing of production has catalyzed further movement of Sandia research into "Pasteur's Quadrant." In a sense, production brings a new type of energy and innovation – a diversity – to the research efforts at Sandia. However, for benefits in both directions, collocation is a necessary, but not sufficient, factor. Management must be engaged and committed, and time and effort are essential.

Fourthly, the change from a traditional model to a collocation model should not be construed in any way as an easy path. Deep cultural and historical precedents, particularly in the realm of human interactions, must be transformed to meet a new framework for partnership between design and production. Clear definition of roles and responsibilities is a critical step in minimizing the conflict inherent to this type of cultural shift. Further, a healthy wariness should be applied towards decisions that will diminish design's capabilities with the incoming production mission. The decision to place development and production on the same floor with the same equipment was not a prudent one. Indeed, for a successful transition, both design and production must be vested in the process from start to finish, playing an active role, understanding the implications of decisions, and having accountability for the results of those decisions.

Finally, the NG mission transfer can be seen as an instructive example of the hazards of designing to stockpiles (1) that are only notional and (2) on the small end of the notional range. Foresight, planning, and investment, in the form of contingency production capacity or plans to implement baseline changes prior to commencement of WR production, could have alleviated the need for the "Rapid Reactivation" program and the accompanying risks and costs.

Appendix A

Appendix A: Alternative Calculation of "Payback" Internal Rate of Return

- The Internal Rate of Return (IRR) is defined as the interest rate that makes net present value of all cash flow equal zero
- The Nonnuclear Reconfiguration (NNR) investment at Sandia for the transfer of NG production capability began in FY94 and continued through FY98
  - Pinellas production of NGs ended in FY94, initiating the savings in Pinellas overhead (OH) in FY95 (and the absorption of OH at Sandia)
- The table illustrates that the **IRR = 0%** between FY98 and FY99 (4-5 years after project initiation)
- No reference to an IRR or **hurdle rate** was found when reviewing original NNR decision-making documents

	FY94	FY95	FY96	FY97	FY98	FY99	FY00
Approx. NNR Investment	$7.1	$33.4	$38.5	$33.7	$23.8	$0.0	$0.0
Approx. Pinellas OH Savings*		-$34.0	-$35.0	-$35.8	-$36.4	-$37.2	-$38.4
Approx. Sandia OH Increase*		$3.8	$3.9	$4.0	$4.1	$4.2	$4.3
Total	$7.1	$3.2	$7.4	$1.9	-$8.5	-$33.0	-$34.1
IRR					**-27%**	**23%**	**38%**

*Indexed for inflation: CPI, U.S. Bureau of Labor Statistics

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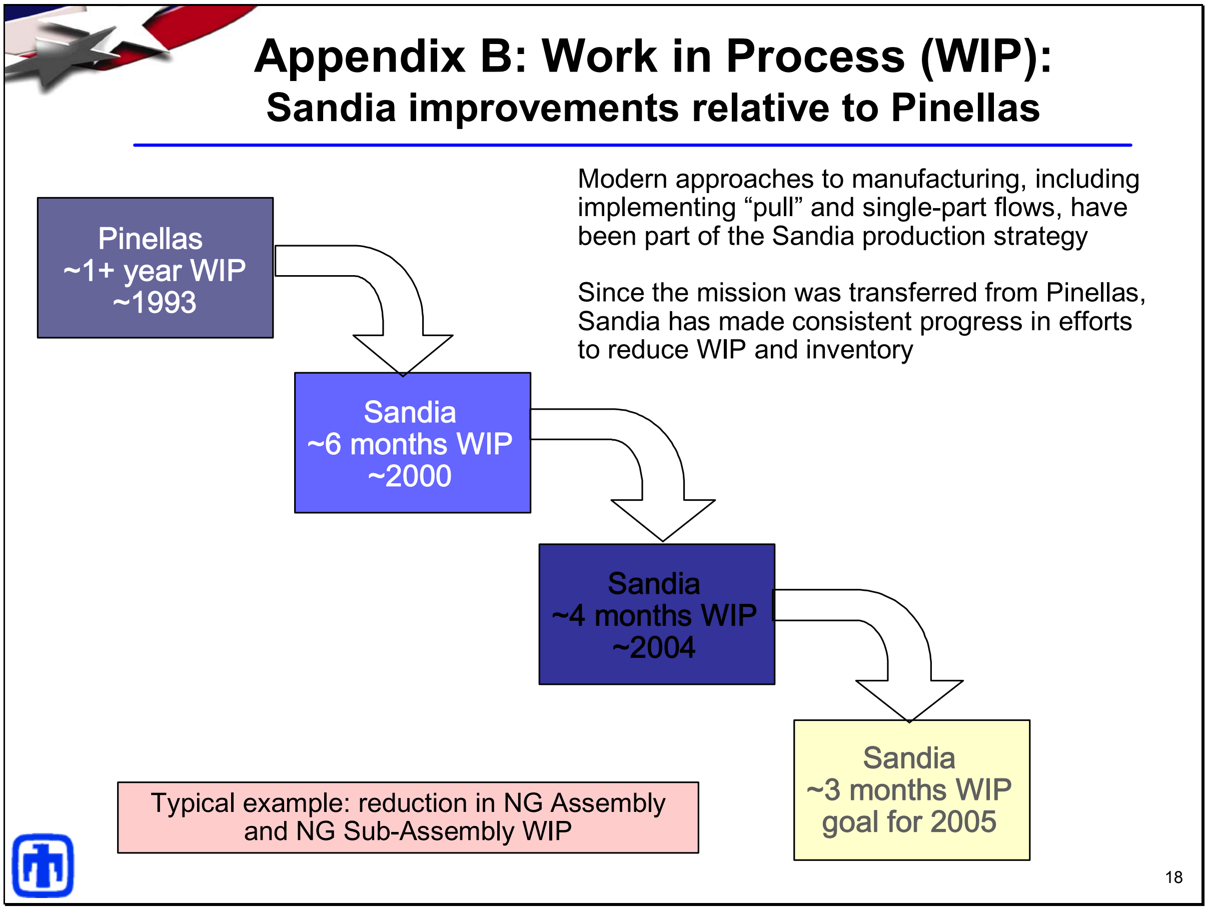
Appendix B


Appendix B: Work in Process (WIP):
Sandia improvements relative to Pinellas
Pinellas ~1+ year WIP ~1993
Sandia ~6 months WIP ~2000
Sandia ~4 months WIP ~2004
Sandia ~3 months WIP goal for 2005
Modern approaches to manufacturing, including implementing “pull” and single-part flows, have been part of the Sandia production strategy
Since the mission was transferred from Pinellas, Sandia has made consistent progress in efforts to reduce WIP and inventory
Typical example: reduction in NG Assembly and NG Sub-Assembly WIP
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