The design of an efficient management structure for the diverse activities contemplated for the Digital Opportunity Investment Trust (DOIT) can be built on lessons learned from a variety of projects facing similar challenges in the past. Strategies have been debated since Jefferson challenged Hamilton's aggressive proposals in his 1791 ***Report on the Subject of Manufacturers***[1]. The Morrill Act itself was designed both to encourage education in the agricultural and mechanical arts but also to produce useful inventions and discoveries in these fields. A provision of the act stipulates that "An annual report shall be made regarding the progress of each college, recording any improvements and experiments made, with their cost and results, and such other matters, including State industrial and economical statistics, as may be supposed useful."[2] Federal research launched some of the great technical revolutions from Eli Whitney's successful implementation of interchangeable parts for muskets (he was late and had a cost overrun), the Morse telegraph, jet engines, the internet, and many others. There have, of course, been some spectacular blunders – it can be politically painful to turn back from a failure – but on balance the record is spectacular. Debates today are not so much over whether the federal government should invest in research but how, where, and how much should be invested.

> If there be anything in a remark often to be met with--namely that there is, in the genius of the people of this country, a peculiar aptitude for mechanic improvements, it would operate as a forcible reason for giving opportunities to the exercise of that species of talent, by the propagation of manufactures.
> *Alexander Hamilton*, *1791*

DO IT's mission is unique and therefore no existing mechanism can be applied without considerable modification. The innovations developed by DOIT will, for example, provide an array of developments that private firms will convert into marketable products and tools. It's likely, for example, that a majority of the ultimate consumers of the goods and services will in fact be schools and training institutions that are operated by public agencies of local, state, and federal agencies. DOIT will support research, but unlike an ordinary research operation, it will also produce key products and services based on this research. Just as PBS was established to fill an educational niche in broadcast television not served by commercial broadcast firms, DOIT will provide key learning software and other materials to fill needs not served by commercial software companies.

1. Research Management

The US now spends in the order of $123 billion annually on research and development (see Box A) of which about 22% is for basic research, 22% for applied research, and 56% is for development. About half of all research funding is spent by the Department of Defense. Funding for education technology research is difficult to pin down since it is supported by several agencies. A reasonable estimate is that total

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[1] REPORT ON THE SUBJECT OF MANUFACTURES, Alexander Hamilton, December 5, 1791 (Printed in the Executive Intelligence Review, January, 1992)

[2] Act of July 2, 1862, ch.130, 12 Stat.503,7 U.S.C.301 et.seq

spending is on the order of $200-300 million per year – with the DoD accounting for the vast majority of this spending.

The funding is allocated using a using a variety of mechanisms under a wide variety of authorities (see Box B for a summary of relevant legislative authorities). Research funding mechanisms include:

- Direct federal management of the research process (e.g. the NASA manned space program or NIST's work on standards and metrics)
- Government Owned and Government Operated Laboratories (GOGOs) and Government Owned and Corporate Operated (GOCOs) such as the Department of Energy's national Laboratories, Federally Funded Research and Development Centers (FFRDCs) such as MITRE and the Institute for Defense Analysis, and other laboratories. Altogether there are more than 700 such facilities employing over 100,000 scientists.[3] The organizations typically conduct the bulk of their work in their own facilities but can also manage external contracts with university or corporate research organizations or arrange for Cooperative R&D Agreement (CRADA) agreements in which government and private research organizations agree to collaborate without direct transfer of funds.
- Competitively funded, investigator-initiated, peer-reviewed grants to universities, businesses, and consortia funded through organizations such as NSF, and much of NIH. These programs can also fund multi-year, multi-participant research partnerships such as the Semiconductor Research Corporation and the NSF Research Centers.[4]
- DARPA's traditional approach of giving an ambitious research challenge and significant resources to a single program manager with great flexibility about how to manage the research. (in recent years DARPA has focused much more heavily on delivering practical products that can have measurable military significance within 3 years)

Box A

Federal R&D Spending
FY 2004 request

Agency	**Millions of $**
Defense	62,753
Health and Human Services/NIH	28,031
NASA	11,009
Energy	8,535
NSF	4,062
Agriculture	1,943
Veterans Affairs	1,232
Commerce/NIST	1,190
Homeland Security	1,001
Transportation	693
Interior	633
EPA	556
Other	1,100
TOTAL	**122,738**

Budget of the United States, Analytical Perspectives, OMB

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[3] C. Dan Brand, Chair, Federal Laboratory Consortium (FLC), "Leveraging our Federal Research and Development (R&D) Investment Through Technology Transfer", Testimony before Committee on Commerce, Science and Transportation, Subcommittee on Science, Technology and Space, U.S. Senate, April 15, 1999

[4] For a recent review of research partnerships see Wessner, Charles W. Editor, "Government-Industry Parternships for the Development of New Technology" National Research Council, 2003.

- Directed set-asides for small businesses through the Small Business Innovation Research (SBIR) program.

Each of these approaches was designed to meet specific agency needs and the period in history when the programs were begun. To determine which, if any of them, is best suited for the research needed, it's essential to start by stating the criteria that must be met. A learning science and technology program built around the research roadmap prepared by the Learning Federation must support:

- a broad portfolio of research ranging from basic research to demonstrated tools and systems.
- mechanisms for combining government and corporate research funds
- continuous feedback from institutions attempting to use the tools developed in practical environments
- interdisciplinary teams
- close collaboration between business, academic, and government research, development, and demonstration teams
- projects that can involve significant numbers of people working together for multiple years
- provision for cutting projects and approaches that are failing
- contractual flexibility allowing fast response, and utilizing talent wherever it can be found (university, corporate, NGOs, elsewhere)
- international collaboration where appropriate.
- research that private firms can convert into practical products
- an ability to attract creative research managers respected by the research community.

What won't work:

The criteria just described are unlikely to be met by attempting to build a new institution that would hire the talent needed to undertake the research itself. The National Laboratory system, for example, was put together to meet World War II requirements for quick development and high secrecy. Technology transfer and collaboration with unclassified university research were post-war afterthoughts.

At the other extreme, a focused research portfolio aiming at practical results and continuous improvement can not be managed by waiting for individual investigators to propose concepts. The research roadmap outlines clear research goals, some of which require fundamental discoveries and some of which require sustained engineering development. The NSF does, however, enjoy a reputation for integrity and independence because of its strong National Science Board and the fact that the Director's 6-year appointment means continuity of management even if there are major political realignments in the White House and Congress.

What might work:

The research management needs of the Learning Federation are in many ways analogous to modern requirements of military research and development. The DoD has recognized that its research is often most effective when it's directed in ways that help private firms develop innovative new products that will ultimately be purchased by the

Department of Defense. A generation ago this process proceeded under the premise that DoD would (a) be the first customer and (b) be able to purchase enough of the product to justify the private firm's production. In the past decade, this assumption can no longer be made since state of the art products resulting from DoD research often find their way into commercial products. Examples include the development of new materials and computer chips which are used in video games before they are used for Defense purposes. Large as it is, DoD markets for new technologies are simply not big enough to justify initial production and marketing investments. As a result, DoD research has shifted dramatically to support rapid technical advances in areas where rapid commercial innovation will result in products directly relevant to DoD needs.

A research management strategy that could draw on some of the best features of DoD (particularly DARPA) and NSF research would have the following characteristics:

- A clearly defined roadmap identifying goals and priorities for achieving them that is regularly updated after consulting with experts in business, universities, and government
- A strong team of program managers with a very small staff each assigned a major component of the roadmap
- Flexibility in research management (e.g. "other transactions authority") allowing fast response to new opportunities and an ability to draw on expertise wherever it may be found.
- Freedom to establish new research centers – including corporate and university partnerships – that can focus effort on a task for at least 3-5 years.
- The ability to establish a captive research center (analogous to work conducted on the NIH campus) if, and only if, the Board is convinced that such a capability is needed.

Box B
Legislation Governing Federal R&D

- **Stevenson-Wydler Technology Innovation Act (1980).** This Act required federal laboratories to facilitate the transfer of federally owned and originated technology to state and local governments and the private sector. The Act includes a requirement that each federal lab spend a specified percentage of its research and development budget on transfer activities and that an Office of Research and Technology Applications (ORTA) be established to facilitate such transfer.
- **Bayh-Dole University and Small Business Patent Act (1980).** This Act permitted government grantees and contractors to retain title to federally funded inventions and encouraged universities to license inventions to industry. The Act is designed to foster interaction between universities and the business community and provided, in part, for title to inventions made by contractors receiving federal R&D funds to be vested in the contractor if they are small businesses, universities, or not-for-profit institutions.
- **Small Business Innovation Development Act (1982).** This Act established the Small Business Innovation Research (SBIR) Program within the major federal R&D agencies to increase government funding of research with commercialization potential in the small high-technology company sector. Each federal agency with an R&D budget of $100 million or more is required to set aside a certain percentage of that amount to finance the SBIR effort.
- **National Cooperative Research Act (1984).** This Act eased antitrust penalties on cooperative research by instituting single, instead of treble, damages for antitrust violations in joint research. The Act also mandated a “rule of reason” standard for assessing potential antitrust violations for cooperative research. This regulation contrasted with the per se standard by which any R&D collusion is an automatic violation, regardless of a determination of economic damage.
- **Federal Technology Transfer Act (1986).** This Act amended the Stevenson-Wydler Technology Innovation Act to authorize Cooperative Research and Development Agreements (CRADAS) between federal laboratories and other entities, including state agencies.
- **Omnibus Trade and Competitiveness Act (1988).** This Act established the Competitiveness Policy Council and created several new programs. (Among these are the Advanced Technology program and the manufacturing technology centers.) These are housed in the Department of Commerce’s National Institute of Standards and Technology and are intended to help commercialize promising new technologies and to improve manufacturing techniques of small and medium-size manufacturers.
- **National Competitiveness Technology Transfer Act (1989).** Part of the DOD authorization bill, this act amended the Stevenson-Wydler Act to allow government-owned, contractor-operated laboratories to enter into cooperative R&D agreements.
- **Defense Conversion, Reinvestment, and Transition Assistance Act (1992).** This Act initiated the Technology Reinvestment Project (TRP) to establish cooperative, interagency efforts that address the technology development, deployment, and education and training needs within both the commercial and defense communities.
- **Small Business Technology Transfer Act (1992).** This act established the Small Business Technology Transfer program (STTR), which seeks to increase private sector commercialization of technology developed through Federal R&D. The program encourages research partners at universities and other non-profit research institutions to enter formal collaborative relationships with the small business concerns. Federal agencies with extramural R&D budgets over $1 billion are required to administer STTR programs using an annual set-aside of 0.15 percent. The set-aside will increase to 0.3 percent in FY2004.

Reproduced from Wessner 2003, p. 102

2. Managing program development

While DOIT will support research, it will also be charged with operating a number of programs designed to deliver products and services directly to the public. These could include:

- Providing funds to libraries, museums, and other institutions to capture text, images, 3-D models of artifacts, buildings and other structures, landscapes and other interesting objects in digital form and for making them available;
- Supporting the development of key software tools that can be incorporated into commercial instructional products. These could include simulations of biological and physical phenomena and simulations that could support immersive games and adventures in specific historic locations;
- Developing and operating complete curricula in areas neglected by commercial firms (or equivalently investing in ambitious new learning systems that could be tested on a wide basis with the expectation that commercial systems would replace them once the concepts are established);
- Providing assistance and policy advice on intellectual property, interoperability of software components, and other legal and technical issues; and
- Supporting teacher training to encourage the use of these tools and resources in classrooms.

Design goals for a management system capable of supporting DOIT work outside of research should include an ability to:

- build and dissolve teams as needed;
- attract high quality staff in many disciplines (cognitive science, information science, law, etc.);
- contract flexibility and assemble private-public partnerships quickly;
- encourage projects jointly funded by federal funds and funds available from corporate, foundation, and other sources; and
- combine in-house staff capabilities and "virtual" centers that may operate from a university or other site.

As in the case of federal research management, there are many models for public support to choose from. An initial question is whether the programs could best be managed as an extension of an existing agency or whether a new organization should be formed. None of the major agencies appear well suited to the task of managing the kinds of works described earlier. Research organizations such as NSF are not organized for such operational missions, although NSF does have a small program that funds IMAX movies, science museum projects, and other nontraditional educational materials. And NSF has supported development of instructional technology on a limited basis. The Department of Education had several software development programs started during the 1990s but most, if not all, have been eliminated and replaced with block grants to states.

Box C **Federal Independent Agencies**[5]	
	FY 2004 budget $millions
Corporation for Public Broadcasting	380
National Foundation on the Arts and the Humanities	
Arts	104
Humanities	153
National Commission on Libraries and Information Science	1
Smithsonian Institution	480
Holocaust Memorial Museum	48

If a new organization is contemplated, there are many options to consider. The federal government has approximately 100 "independent agencies" including everything from the "Defense Nuclear Facilities Safety Board" to the "Barry Goldwater Scholarship and Excellence in Education Foundation". Box C lists some relevant models and their level of funding.

There are many analogies between DOIT's mission and the mission of the Corporation for Public Broadcasting. CPB was formed to fund educational television because commercial networks couldn't justify the investment. {include a brief critique of what would need to change to make a CPB model work? Larry can help?}

3. ***Management Independence***

There is broad agreement that DOIT's activities require a management structure that provides ultimate accountability to the Congress, but that also ensures the management can enjoy the stability and independence from political interference needed to ensure a high quality product. The National Science Foundation provides a widely acceptable model for meeting this goal. Its Director is appointed to a 6-year term and reports to a strong, independent board. This model was also used in the newly authorized Office of Innovation and Improvement in the US Department of Education. {check}

[5] OMB.