

National Photonics Initiative

White House Strategy for American Innovation 2014

INTRODUCTION

Crucial breakthroughs in the fields of optics and photonics have led to technologies that help form the infrastructure of many US industries and provide essential technologies for national defense and security. Photonics – the study and use of light – enable nearly every commercial sector, from advanced manufacturing to information technology and energy to medicine. Historically, the United States has been the world pioneer in transitioning photonics research to commercial markets; however, increased global competition has put at risk our nation's leadership position, threatening national security, economic growth and the pipeline of US jobs. Photonics is a platform technology, an enabling technology, and it must be part of any innovation strategy developed in the 21st century.

To maintain US competitiveness and retain American jobs in a number of dramatically growing commercial- and defense-related areas, the National Photonics Initiative (NPI), a collaborative alliance of industry, academia and government experts, has identified critical technology challenges and made recommendations for strategic investments in infrastructure to the US government. On behalf of the optics and photonics community, the NPI hopes our Response for Information highlights areas for public and private sector investment and support that best address the White House's Strategy for American Innovation.

OVERARCHING QUESTIONS

Response to Question 1

1.1 Fabrication and prototyping centers (Institutes for Manufacturing Innovation model)

The NPI advises the US government to consider an end-user-driven approach to identifying competitive photonics technologies and developing the most effective manufacturing processes, which will provide significant benefit to the US economy and job creation in several major industries, and increase innovation in both academia and federally funded research and development (R&D) centers. We emphasize that it is essential that private industry, academia and government work closely together to identify joint investments in appropriate, commercially viable photonics technologies. This program should be implemented in evolving stages, and it should actively engage US industry at each stage as an integral participant in co-funding this initiative and ensuring its success.

Innovation is dramatically enhanced when R&D teams can rapidly explore the feasibility of new concepts by assembling prototypes and evaluating cost-effective manufacturing processes. This occurred with spectacular fashion during the 1980s in the semiconductor industry. Technologists in academic institutions, small and large companies and government laboratories were enabled by the government-initiated Metal Oxide Semiconductor Implementation Service (MOSIS) program to inexpensively prototype electronic integrated circuits. Photonics is poised to unleash the coming era of inexpensive and energy-efficient data center and computational technologies through photonic

integrated circuits (PICs) for industrial and consumer devices requiring high data bandwidths, such as next-generation, super-resolution 4K displays.

Although a “foundry” for photonic integrated circuits has been a recommendation of every major optics and photonics study from the US National Academies of Science dating back to the 1970s, we still have not succeeded in lowering the prototyping barriers for PICs at any scale comparable to existing IC/semiconductor foundries. Recent developments in PIC technologies have evolved to a stage where multiple devices and capabilities can be designed from a common platform. Several countries (e.g., Belgium, China and Singapore) have recognized this evolution and are starting to provide some limited prototyping using specific platform technologies.

It is imperative that the US government help form a National Photonics Prototyping and Advanced Manufacturing Facility. By taking a leadership role in the formation of such a facility, the US government would not only stimulate economic growth and American jobs, but it would also launch a new frontier of opportunities for innovation. Even basic light sources, such as LEDs and lasers, have already shown enormous applicability in military systems, consumer electronics, urban infrastructure, medical diagnostics and advanced manufacturing – this list grows dramatically when other types of devices are included. Moreover, providing a platform for prototyping novel devices that combine optics and photonics with electronic integrated circuits, and exploring new methods for manufacturing these devices, will propel the next generation of communication, sensor, information and display technologies. With rising concerns about cyber-physical security, a national facility would ensure that a viable “first and assured access” supply chain of devices and technology fabrication is available within the United States.

A prototyping and advanced manufacturing facility will help develop the ability, skills and knowledge necessary for the United States to ensure its competitiveness and leadership in optics and photonics technologies critical to our national security and prosperity.

1.2 Photonics research at the intersection of biology and physics

The NPI is convening a Photonics Industry Neuroscience Group (PING) to focus on developing new optics and photonics technologies in support of the White House Brain Research through Advancing Imaging Neurotechnologies (BRAIN) Initiative. The NPI PING is comprised of top US industry leaders who will work closely as a group with the BRAIN leadership and neuroscience research communities to advance optics and photonics research and technology development.

The NPI industry group will commit to invest tens of millions of dollars in existing and future research and development spending over the next three years to advance optics and photonics technology in neurosciences challenges such as:

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- Develop the imaging optics, laser sources and automated scanning technology and high-resolution cameras to provide a ten-to-one hundred fold increase in the capability of imaging groups of thousands of active neurons;
 - Develop miniature, affordable and portable/implantable microscopes compatible with high-throughput facilities for therapeutic screening based on neural activity signatures;
 - Using large-scale, high-throughput protein engineering technology, develop a new generation of fluorescent indicators of neural activity with tenfold improvements in efficiency and temporal response; and
 - Develop automated software for detailed mapping of the human brain, architecture, neuronal wiring geometry and dynamic activity from three dimensional data sets generated by MRI, CT and microscopic imaging.

1.3 Development of sensing technologies for fuel extraction and utilization

Optical sensor technology is essential for efficiently developing and utilizing US energy resources. The United States uses more than 100 billion gallons of gasoline and nearly 300 trillion cubic feet of natural gas every year; a 1 percent increase in efficiency would save more than \$50 billion dollars in fuel costs and reduce carbon dioxide emissions by more than 30 million metric tons. This objective can be accomplished by creating domestic sources for:

- Novel optical materials for sensors of critical oil and gas parameters;
- Exotic light sources and detectors for tracking combustion performance and emissions; and
- New methods for imaging geophysical properties through complex media.

Investing in a multi-site initiative to develop these critical photonic technologies will make America the leader in monitoring energy extraction and utilization at scales ranging from the oilfield to the engine.

1.4 Development of sensing technologies for agriculture

The demand for ever more efficient agricultural production has fostered a high-tech area referred to as Ag Tech. Particularly in Unmanned Aircraft Systems (UAS), markets around the globe in both developed and developing nations are quickly adopting this technology, which is providing them a host of data-gathering capabilities enabled by optics and photonics. This highly innovative space in the United States has, however, been stifled due to current laws prohibiting commercial use of UAS technology and the Federal Aviation Administration's (FAA) inability to finish modern guidelines – discussed further in section 2.2.

At the core of agricultural technologies, integrated photonic devices are common price-limiting components. Since the scientific field supporting this area is still growing, tools sold to farmers are unable to be targeted-sensing systems and are therefore costly. Along with the recommendations outlined in section 1.5, a thrust in agricultural research focused on spectral sensing would produce a body of knowledge and the corresponding tools needed to meet the demands of climate disruption.

1.5 Device and systems-level research in photonic integration

The global marketplace is ripe for a renaissance in photonic sensor technology. Delivery of small, low-cost sensor systems of this type will open wide existing industries as well as those that are just merely a dream. Photonic sensors are already being integrated into devices in our homes, cars and phones. These inroads, however, are just the tip of the iceberg. Photonic technology will emerge in the 21st century in ways comparable to the electronic revolution of the 20th century, and at its center are materials engineered for emission, transmission and detection of light.

Electronics began in this same way, addressing technological problems here and there, and promising a future of integrated devices. Nearly 70 years later, this market is dominating the global economy and is a key driver in improving quality of life. The NPI recommends a public-private partnership, where government-matched industry R&D funding is used to develop a clearinghouse of photonic materials, complete with standardized specifications, practices toward scalable fabrication, and the balance of systems required to make these materials perform at the peak of their potential.

Investing in establishing and standardizing photonic sensor integration and light-wave management processes will open wide the global application space of these technologies. US leadership in photonic sensor integration know-how and technology will spur economic growth, create US jobs and provide a cost saving to government agencies such as the Department of Defense (DoD) and National Oceanic and Atmospheric Administration (NOAA) by reducing the cost of environmental sensing tools.

Low-cost photonic sensors that enable real-time and distributed monitoring (individual sensors linked to a common data collection site) will benefit all facets of society by providing:

- Pipeline fault monitoring, down-well sensors for harsh environments and fuel-ship transportation sensors for the efficient exploration, extraction and consumption of fossil fuels;
- Soil content sensors, aerial crop health imaging and experimental growth condition illumination for agriculture;
- Stress monitoring for turbine blades in wind farms to promote energy production efficiency;
- Live safety and health indicators for drinking and coastal waters; and
- Monitoring for pollution to lower environmental impact.

1.6 Fundamental materials timeline to market

Without knowing it, most Americans carry a dense visible spectrum sensor array around with them every day in the form of a camera phone. Great opportunity now exists to bring low-cost sources and detectors to the market, from deep UV to the thermal infrared. The primary obstacle is the cost associated with bringing new material systems to market. The NPI recommends that the US government commit to an extended timeline and path to capture the know-how and fabrication processes necessary to fill out the working range of optical material systems for detection, emission and manipulation of light. This is key for materials research, which has many long-term equipment maintenance costs. The benefit of such an investment is domestic access to an array of materials –

engineered materials that take raw elements out of the earth and grow them like semiconductors, glass and electrical contact materials – that liberate the design process for innovators to develop a diverse new set of capabilities in a cost effective way.

1.7 Laser materials processing

Advanced manufacturing is vital for the economic well-being of the country; it is a sector in which substantial job growth is possible. Though the majority of display and photonics component manufacturing has moved overseas, the United States can be a leader in new and innovative areas of manufacturing involving a new generation of high-power and low-cost ultra-short pulsed lasers, as well as additive manufacturing, a subset of 3D printing. Additive manufacturing allows machines to make a range of customized products directly from electronically transmitted designs, saving costly material in the process. It allows fabrication of parts with novel material compositions and can simplify manufacturing of complex shapes. These advanced printers, which President Barack Obama called the future of manufacturing, can create objects ranging from prosthetic limbs and functional human tissue to jet engine parts and shoes. While the United States may struggle to compete successfully in high-volume, labor-intensive, low-cost manufacturing, our nation can be a strong competitor in custom, precision and high-added-value manufacturing.

The NPI recommends that the United States invest in a coordinated national effort to improve our understanding of laser-material interaction for applications in heavy industry and manufacturing for material processing of metals, ceramics, plastics, composites and glass. Such an investment will benefit the capture of manufacturing process know-how and access to domestic capabilities that will drive the production of the consumer and industrial products of tomorrow.

1.8 High-Energy Lasers and Systems for Defense and Advanced Manufacturing

Photonics is a major part of many high-performance systems used by the military and in advanced manufacturing. The use of photonics technologies in advanced manufacturing has improved key factors of production such as product size, weight, performance and cost. As such, photonics are a driving force behind the revitalization of manufacturing in the United States and have become an essential tool for the factory of the future. Today, high-power lasers are increasingly used in industry for cutting, welding, drilling, surface modification and additive manufacturing, and they play an increasing role in the manufacturing of military hardware.

High-power laser weapons strike at the speed of light. They are recognized as imminently viable for cost-effective defense against a variety of proliferating weapons. Modest-power lasers are widely used by the military in surveillance and guidance. Currently, they are used for protection against heat seeking missiles, but they may also prove effective in disabling satellites in the near future.

US leadership in high-field physics will require leadership in high-power lasers, as Europe moves to complete its version of the National Ignition Facility (NIF) and separately establish the equivalent of the CERN particle accelerator for laser technology.

Response to Question 2

2.1 Education to meet optics and photonics industry demands

Curriculum pipelines lag far behind the demands of the optics and photonics industry. This challenge is recognized by many progressive technology fields, and the cause is largely related to a lack of communication avenues between industry and academia.

Similar to other science and technology areas, work force training programs, including wide-ranging educational activities, are needed to ensure a skilled US optics and photonics work force. Education and training are needed for advanced, multidisciplinary research, laboratory protocols, design and packaging skills, and certification programs for skilled technicians. Optics and photonics jobs require a variety of educational levels that range from community colleges to graduate students and post-doctoral researchers.

2.2 Emerging photonics technologies and existing regulatory landscape

Truly disruptive innovations commonly come into conflict with existing regulation. An area of much excitement around the world, and one discussed in response to other questions in this letter, is biophotonics – a field promising leaps forward in medical device technology. Presently, however, the expense necessary to clear US Food and Drug Administration (FDA) filings for medical devices in both currency and time is a major hindrance to innovation, specifically with regard to time-to-market.

Biophotonics has begun to open the agricultural markets to advanced sensing technology. Unmanned Aircraft Systems (UAS) carrying spectral imagers are being adopted by farmers around the world in the hopes of alleviating water shortages and boosting crop yields. Yet, in the United States, the FAA has been slow to complete guidelines for these types of aerial systems, stalling an innovative market place that is ready for adoption.

2.3 New financing mechanisms

As optics and photonics hardware development struggles to secure investment from the finance community, crowdfunding has emerged as a promising alternative method for raising capital. The US Securities and Exchange Commission (SEC) has yet to finalize guidelines for equity crowdfunding based on Congress' 2012 "Jumpstart our Business Startups (JOBS) Act. While there is indeed room for this type of investment for optics and photonics hardware development, many innovative projects are stalled due to the slow turnaround speed of the SEC for defining crowdfunding regulations.

Global success is strongly tied to how well the private sector can predict the future and assess risks. Recently in the United States, research funding has become undependable, and existing regulatory processes have been greatly stifling to innovation. The modernization of the US regulatory framework across agencies is vital for small and large business to remain competitive in the world marketplace.

Response to Question 3

3.0 Technology infrastructure investments

There are a group of related technology areas ripe for national support. Infrastructure recommendations include investment into prototyping facilities for telecommunications technology, sensing systems for energy and environmental challenges, and high-energy laser systems development. Research thrust areas that represent the future of economic and health well-being around the world include biophotonics, fundamental materials fabrication, and laser-material interactions. The NPI has gathered task forces and working groups charged with dissecting these areas and offering input. Please reference sections **1** and **2** for more information.

Response to Question 4

4.0 *The NPI has no unique contribution to this question.*

Response to Question 5

5.0 *The NPI has no unique contribution to this question.*

INNOVATION TRENDS

Response to Question 6

6.1 Open-Innovation model

Electronics enjoys the benefits of having grown up in the Bell Labs era which saw grand public and private investment into standardization and process development around components to make the integration of components easy and approachable by those novice to the field. Since then, the United States has moved away from this type of direct industry-partnered investment in order to avoid biasing free market competition. In today's funding vacuum, a few models, including open innovation, have emerged to compensate.

Aided by moving advanced science into the hands of industrial partners, open innovation is a model by which a company looks outside its four walls and seeks to partner with experts around the world in the innovative areas necessary to their continued business success. This is particularly relevant in photonics, as the cutting edge is generally far from industrial practice. Fields of science like optics and photonics are not currently part of the core competency of companies – particularly small, innovative companies – and so they struggle to internalize the expertise necessary to overcome the integration of photonic components.

An open innovation initiative could be envisioned to create a “technology commons” in the United States, where researchers could better market their results to the nationwide body of commercial players interested in adopting new product advances or manufacturing processes.

6.2 More Effective Technology Transfer

Over 30 years ago, the Bayh-Dole Act gave US universities – as well as small businesses and nonprofit organizations – the ability to control intellectual property (IP) that results from federal government-funded research. The intent was that with a stake to claim, universities would be more effective in moving technology from the lab to the market than government, and in so doing, impact our society faster. The Bayh-Dole Act has accomplished what it set out to, but as academic institutes, many universities put very little effort or resources into the proactive licensing of their IP. Generally, technology transfer offices run at or near zero-net profit and more importantly have huge portfolios of technology sitting around gathering dust.

There is opportunity for the administration to foster university technology transfer through similar means, as discussed above, in regard to open innovation. A “national IP commons,” made searchable for technology type, would bring visibility to this massive pool of cutting-edge technology that is otherwise daunting to the industrial technologist.

Response to Question 7

7.0 FTAC-OP

This spring, the National Science and Technology Council produced a report of the Fast-Track Action Committee on Optics and Photonics (FTAC-OP). Outlined in the report was a prioritized list of seven recommendations, which are organized into categories of research opportunities and research-related capabilities. The research opportunities address: biophotonics to advance understanding of systems biology and disease progression; faint to single photonics; imaging through complex media; and ultra-low-power optoelectronics.

The research-related capabilities, which will encourage innovation in optics and photonics research, are: accessible fabrication facilities, exotic photonics and domestic sources for critical photonic materials.

The NPI has seen these same priorities emerge in ongoing work with industrial and academic partners. As this report states, “Progress in the field of optics and photonics has the potential to generate new knowledge, promote economic growth, create new industries and new high-skilled jobs, and provide technologies for new applications.”

On July 22, 2014, the National Science Foundation (NSF) identified optics and photonics research and education as a key area of interest. Charged with keeping the United States at the leading edge of discovery across a broad scope of scientific areas, the NSF is calling for innovative research proposals on optics and photonics that are relevant to one or more of the following: Divisions in the Directorates for Engineering (ENG), Mathematical and Physical Sciences (MPS), and/or Computer and Information Science and Engineering (CISE). Areas that would benefit from such broad research support include the Materials Genome Project, photonic integration and laser material processing. Other federal research agencies should follow NSF’s lead to call for optics and photonics proposals in a single or multidisciplinary approach.

Response to Question 8

8.0 The NPI has no unique contribution to this question.

SCIENCE, TECHNOLOGY, AND R&D PRIORITIES

Response to Question 9

9.0 Discussed above in response to questions #1 and #2

The field of optics and photonics is one that defines a platform technology. The capabilities that have emerged from this field are firmly embedded in every piece of modern technology around the world. The future of innovation will undoubtedly depend on further advancements from optics and photonics. Infrastructure recommendations include investment into prototyping facilities for telecommunications technology, sensing systems for energy and environmental challenges, and high-energy laser systems development. Research thrust areas that represent the future of economic and health well-being around the world include biophotonics, fundamental materials fabrication and laser-material interactions. The NPI has gathered task forces and working groups charged with dissecting these areas and offering input. Please reference sections **1** and **2** for more information.

Response to Question 10

10.1 IT Telecommunications

In order to address the challenges of the global communications infrastructure, it is essential to both US economic and security interests to develop a domestic capability to develop and prototype advanced photonic technologies. Please reference sections **1.1** for more information about recommended actions to bring together academia, industry and government.

10.2 Biophotonics

At the intersection of biology and physics, a new field is emerging that promises advancements in neurological diagnosis and treatment. Central to this new field is biophotonics, the ability to measure and manipulate biological systems using light. The United States has a key strength in biomedical research infrastructure, so there is a great opportunity for impactful investment by the US government. This area is discussed in section **1.2** with regard to ongoing work in line with the BRAIN Initiative.

10.3 Sensors for energy and environment

Sensor technology drives myriad capabilities as discussed in sections **1.3**, **1.4**, **1.5** and **1.6** above. It is key that the United States invest in “cradle-to-grave” initiatives for sensor technology that establish materials sources, fabrication techniques, systems integration and user processes. The impact of progress in this area will have direct impacts on fuel costs and crop yield, and indirect but clear impact on environmental quality and domestic quality of life.

10.4 Laser material processing for advanced manufacturing

Manufacturing has been revolutionized by the development of laser technology. Traditional subtractive processing as well as the emerging area of additive processing (3D printing) have been forever changed by the precision and speed of lasers. Additionally, the field of welding and surface patterning is quickly growing in capability due to laser technology. The development of laser systems and processes as applied to manufacturing is discussed further in sections 1.7 and 1.8.

Response to Question 11

11.0 *The NPI has no unique contribution to this question.*

SKILLED WORK FORCE DEVELOPMENT

This year, the NPI launched a Taskforce on Education and Workforce Development (NPI-TEWD) to address questions like those posed in this section. Initial results from this task force indicate that three primary activities are needed from the work force pipeline perspective in the optics and photonics field, as follows:

1. Skills roadmapping: identification and communication of the industry's forward-looking employment needs;
2. Careers marketing: raising the profile and adoption of careers in optics and photonics; and
3. Industry-partnered training: developing on-the-job training through internships, co-ops and apprenticeships.

In order to execute these projects, a sustainable coalition of employers will be gathered. The NPI-

Response to Question 12

12.0 *The NPI is pursuing more concrete responses to this question.*

Response to Question 13

13.0 *The NPI is pursuing more concrete responses to this question.*

Response to Question 14

14.0 *The NPI is pursuing more concrete responses to this question.*

MANUFACTURING AND ENTREPRENEURSHIP

Response to Question 15

15.0 *The NPI is pursuing more concrete responses to this question.*

Response to Question 16

16.0 Industrial-scale user tools

The key to accelerating advanced-technology innovation into commercial practice is access to industrial-scale fabrication and manufacturing tools. Great barriers exist for technology companies of all sizes in transitioning from prototype to production, including financial capital investment and process development. In order to assist innovators in surmounting these barriers, some precedent exists for the establishment of user facilities filled with industrial-scale fabrication tools capable of semiconductor growth, thin film deposition, metal growth and an array of more advanced processes. Commonly, these facilities are the result of academic-industrial consortia, which establish facilities to highlight industrial tools in hopes of attracting customers once capital investment is prepared, while granting cutting-edge capability to researchers and technologists alike.

This need for process development and prototype development is also relevant to responses to question 1.

Response to Question 17

17.1 Open Innovation

As discussed further in section 6.1, Open Innovation has successfully drawn more and more innovative academic research into commercial road maps since its formal conception in 2003. Many large companies have adopted Open Innovation programs, and smaller companies are now learning to adapt the concept to their businesses. It is recommended that the administration drive the creation of a US technology commons to promote access to innovative solutions.

17.2 Crowdfunding

Hardware is expensive to develop and even more expensive to commercialize. In the funding vacuum created by venture capital investors who have set return-on-investment expectations on a trajectory that foreshadows a potential new dot-com bubble, crowdfunding offers a model for bridging the valley of death through direct engagement with customers. It is now necessary to accelerate regulation of this funding model in order to eliminate further stifling of this distributed private investment process. Please refer to section 2.3 for further discussion.

Response to Question 18

18.0 Prototyping Facilities

Proving the potential of new and disruptive technology is currently a challenge to those most capable of creating them. As discussed in section 1.1 and 16.1, the NPI recommends the development of

facilities intended to address exactly this problem by leveraging industrial technology needs and prototyping facility needs of innovators.

REGIONAL INNOVATION ECOSYSTEMS

Response to Question 19

19.0 Industrial clusters

There exist 12 optics and photonics industry clusters around the United States in 11 states:

- Arkansas Photonics Industry Alliance
- Arizona Optics Industry Association
- Carolinas MicroOptics Triangle
- Carolinas Photonics Consortium
- Colorado Photonics Industry Association
- Connecticut Optics and Photonics Association (CTOPA)
- Florida Photonics Cluster
- Michigan Photonics Cluster
- Montana Photonics Industry Alliance
- New Mexico Optics Industry Association (NMOIA)
- New York Photonics Industry Association
- Rochester Regional Photonics Cluster, Inc.

These groups perform an array of services for their membership including networking opportunities, organization for advocacy efforts, organization or regional proposal work, and interfacing with regional educational assets. Largely, however, these associations go underutilized from the national perspective. Potential exists to leverage existing organizational structures, like the optics and photonics clusters across the United States, to nucleate activities within the scope of the administration's technological priorities.

Response to Question 20

20.0 *The NPI has no unique contribution to this question.*

Response to Question 21

21.0 *The NPI has no unique contribution to this question.*

NOVEL GOVERNMENT TOOLS FOR PROMOTING INNOVATION

Response to Question 22

22.0 *The NPI has no unique contribution to this question.*

Response to Question 23

23.0 *The NPI has no unique contribution to this question.*

NATIONAL PRIORITIES

Response to Question 24

24.0 Photonics: An American platform for 21st century innovation

Discussed throughout this response, optics and photonics technologies present themselves as enabling capabilities. All fields of science and all high-tech industries depend vitally on advances in this field. Furthermore, there is great opportunity for the United States to capture a global leadership role in the implementation of these technologies by investing in infrastructure projects that:

1. Establish the United States' ability to fabricate specialty materials;
2. Integrate materials into sensor devices;
3. Prototype systems with industrial input; and
4. Manufacture systems of increasing precision and accuracy tolerances.

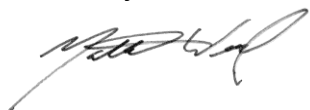
Establishment of The National Photonics Initiative was recommended by a National Academy of Science committee of academic, industrial and agency leaders in order to communicate the commercially disparate but immensely impactful field of optics and photonics to decision-makers in the US government. The voice of the telecommunications, biomedical, energy, defense and advanced-manufacturing communities around the United States is therefore captured in the responses to this request for information.

Response to Question 25

25.0 *The NPI has no unique contribution to this question.*

On behalf of the National Photonics Initiative and the community of scientists, engineers, and innovators represented thereby, I thank you for this opportunity.

Sincerely,

A handwritten signature in black ink, appearing to read "Matthew Weed".

Matthew Weed
NPI Steering Committee