



Driving Photonics Manufacturing

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PSMC Sustainability Plan

For the Integrated Photonics Integrated Manufacturing Institute

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PSMC Sustainability Plan

Driving a Photonics Manufacturing Ecosystem

Introduction

PSMC Sustainability Mission Statement: The PSMC will become a vital, industry-sustained infrastructure element within the next five years. The PSMC value proposition is based on three pillars: Roadmap, “Big M” Technology Evaluation, and Supply Chain Integration. The pace of value creation is dependent on the emergence of cost effective, platform-based, high volume photonics manufacturing. Significant adoption of integrated photonics manufacturing is required during the next five years for PSMC to meet its sustainability goals.



Figure 1. Sustainability Mission of PSMC

The Photonics Systems Manufacturing Consortium proposal envisions three phases of development. “Big M” manufacturing practice for Integrated Photonic Systems is defined as coordination and global optimization of every node in the technology and material supply chains: spanning from material synthesis, design-for-X and chip fabrication to assembly, delivery and end-of-life recycling.

Phase 1: June 2014-December 2015

Three value points are being established during this period: i) creation of the PSMC Roadmap and associated Technical Working Groups; ii) development of a complete photonics manufacturing supply chain; and iii) support of an Integrated Photonics Institute for Manufacturing Innovation (IP-IMI).

This period of activity is being funded by the NIST AMTech Program, volunteers from research institutes, and the Big M manufacturing supply chain.

Phase 1 goals:

- Establish a consortium of academics, technologists, and companies that will create an Integrated Photonic Technology Roadmap.
- Bring together the fragmented, customization-focused photonics industry to engage collaboratively in developing a common roadmap.
- Support development of high-volume mass-manufacturing, assembly, and packaging technologies and processes that are reliable and cost-effective.

Phase 2: July 2015-July 2020

Two value points are targeted for this period: i) efficient ‘stand up’ and operation of the Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) and ii) support of Advanced Manufacturing Partnership (AMP) 2.0 goals by creation of “Big M” technology research, development and evaluation centers.

- Establishment of an IP-IMI with PSMC providing the Technology Roadmap support. Funded by a five-year grant from the U.S. Government (DoD-AFRL) and matching contributions from industry, states, universities and research institutes.
- Establish a new public-private manufacturing research and development infrastructure to support the innovation pipeline, which complements Manufacturing Innovation Institutes at earlier and later technology maturation stages, through the creation of manufacturing centers of excellence (MCEs) and manufacturing technology testbeds (MTTs) to provide a framework that supports manufacturing innovation at different stages of maturity and allows small and medium-sized enterprises to benefit from these investments.

Phase 3: July 2020-2035

During this period PSMC will coordinate the establishment of an industry led, self-sustaining Research, Development, and Manufacturing (R&D&M) infrastructure and ecosystem from the IP-IMI, IP-MCE and IP-MTT foundation. Establishment of a cooperating and coordinated end-to-end supply chain will be the gating and sustaining activity for this enterprise.

This document describes our plan for the success of Phases 2 and 3 for the IP-IMI and succeeding entities as specified by our NIST AMTech Grant. As noted throughout our proposal the critical step is to utilize the roadmapping and technical planning process of Phase 1 to bring all stakeholders in both the commercial and military markets together to focus on the key roadblocks or “red brick walls” that cannot be solved without government support to reduce the risk to individual supply chain firms. Achieving this ‘unity of purpose’ within the industry is a daunting task. Milestone charts for all three Phases are provided in an appendix to this report.

Phase 1: PSMC Roadmap, Technical Working Groups, Executive Advisory Board, and Technical Planning for IP-IMI: June 2014-Jan. 2015

PSMC held its initial Roadmap Workshop on November 6-7 in Cambridge MA. Approximately 100 representatives from the research community, government, not for profits, the entire manufacturing supply chain, and technology users (“customers”) attended the meeting. Six months into the program we have identified a key list of attributes and activities to be addressed in Phase 2. Three data sources have been developed:

- Industry brainstorming sessions in Silicon Valley,
- Breakout groups and workshops in Cambridge,
- Leaders of the Technology Working Groups.

They have identified the following attributes for integrated photonics manufacturing success:

- A strong leader and a team with unity of purpose
- Institutional, state and federal collaboration in creating an ‘industrial commons’
- A feasible plan for sustainable independence
- Industry supply chain cooperation and adoption of common manufacturing platforms
- Common platforms with common interfaces for design and process development
- Cooperative R&D&M foundries with assignees from industrial supply chain
- Smart partitioning of electronic and photonic functionality with self-test capability
- A packaging process revolution that reduces assembly steps and layout complexity
- Accurate cost models for evaluation of alternate technologies

The recent Consumer Electronics Show in Las Vegas has demonstrated a multitude of new product concepts that depend on a strong and viable Internet to support the next generation of products. The successful execution of the PSMC roadmap and technical plan is becoming critical to new jobs and growth in the United States economy. During PSMC’s Phase 1, we are establishing a non-fiduciary Executive Advisory Board. The key reasons for establishing this group are to develop trust, cooperation, and shared objectives within a leadership team that is representative of the manufacturing supply chain. The objective is to provide the executive-level industry support that will be essential for a successful

stand-up of an IP-IMI. PSMC has identified the incumbent proprietary culture as a source of the hesitancy of the optoelectronics industry to cooperate and accelerate the broad introduction of “integrated photonics.” During Phase 1 a major effort is being made to build trust and cooperation between the stakeholders. The ‘seat classifications’ for executive members of this board (listed below) reflect the diversity of the integrated photonics manufacturing industry and the organizations participating in the PSMC activities:

1. Produce end-manufactured electronic products ("OEM Representatives"),
2. Produce components, materials, subassemblies or equipment used in manufacturing photonic and electronic products ("Supplier Representatives"),
3. Provide Electronics Manufacturing Services ("EMS Representatives"),
4. Provide integrated packaging (“Packaging Representatives”),
5. Manufacture semiconductor and/or photonic devices (“Foundry Representatives”),
6. Conduct advanced research (University and Research Institutes),
7. Engage relevant stakeholders (not for profit organizations and Government Representatives)
8. Engage technology users (Customers).

The board will include representatives of major firms, and small and medium size enterprises. At this time the following individuals have agreed to participate in this executive board.

Figure 1. Initial PSMC Executive Advisory Board

Organization	Individual	Position	Representing
Alcatel-Lucent	Sanjay Patel	VP, IP Transport	Telecom OEMs
Cisco	Kal Shasti	Distinguished Engineer	IT OEMs
Promax Industries	Richard Otte	President	Small Assembly Manufacturers
MACOM	Richard Grzybowski	Director of R&D	Medium Size Integrated Photonics OEMs
Intel	Bob Sankman	Intel Fellow	Semiconductor Mfg.
NIST			Research Institute
OIDA	Thomas Hausken	Senior Advisor	Stakeholders
Facebook	Katharine Schmidtke	Strategic Sourcing Manager	Commercial Customers
Lockheed-Martin	Dan Blass	Senior Scientist, MST	Military Customers

Milestones

The milestones for Phase 1 of the PSMC activities are discussed at the beginning of this section and in the Appendix of Milestones. They are the roadmapping phase, the development of a product emulator to develop a cost model for success, and the establishment of a technical plan to attract industrial participants to fund an IP-IMI.

Phase 2: IP-IMI with PSMC Support and AMP 2.0: July 2015-July 2020

Introduction

The PSMC is committed to play a major role in the continuing role out of the Administration's Institutes for Manufacturing Innovation and subsequent entities under AMP 2.0. PSMC will cooperate and support all AMP entities in the development of a strong US integrated photonics manufacturing base. In Phase 2 we will offer our experience in establishing an organization dedicated to manufacturing innovation; we will provide data and analyses based on our industry-wide strategic Technical Working Groups; and we will actively compete to partner or lead AMP 2.0 MCEs and MTTs. The PSMC Technology Roadmap and supply chain coordination are critical elements to the IP-IMI core missions of manufacturing technology implementation and job creation. Definition of technology roadblocks and potential solutions will help structure the IP-IMI project requirements; and technology timelines and cost analyses will help forecast the pace and content of the Education and Work Force Development in support of job creation. The PSMC technology targets, production and market data, and gap analyses will give continuous guidance to the IP-IMI strategic objectives.

Leadership of IP-IMI

To address the technology needs and collaborative leadership requirements already identified by PSMC, it is critical for Phase 2 that a standalone IP-IMI organization be established with a strong CEO and a strong Board of Directors with executives/senior technologists that are representative of the user community for the IMI. Both Sematech and iNEMI have shown that this practice was critical to their development as organizations that meet the needs of the manufacturing supply chain.

Board of Directors. We recommend that the IP-IMI Board of Directors be industry (Commercial and Military) led with designated seats for various portions of the supply chain; and with provision for Ex Officio members, similar to the structure being used for the PSMC Executive Advisory Board (EAB). The IP-IMI BoD would have ultimate fiduciary and oversight responsibility for the business, operations, and general affairs of the new organization. At least two members of the board should represent small and medium size enterprises.

The representative structure of the iNEMI Board of Directors as defined in its by-laws could serve as a model for the IP-IMI BoD:

“(a) Elected Directors

The number of Directors shall be established by The Board of Directors, provided that there shall be not fewer than eight (8) Directors or more than twelve (12) Directors. Directors shall reflect the diversity of the electronics manufacturing industry and shall include representatives of iNEMI Participating Organizations: (i) who produce end-manufactured electronic products (“OEM Representatives”); (ii) who produce components, materials, subassemblies or equipment used in manufacturing electronic products (“Supplier Representatives”); (iii) who are Electronics

Manufacturing Services providers ("EMS Representatives") and (iv) other iNEMI Participating Organization Members.

(b) Ex-Official Directors

The Chief Executive Officer and the Chairs of the iNEMI Technical Committee shall serve as non-voting ex-officio members of the Board of Directors. The Board of Directors may appoint government representatives and representatives of research institute members, who work with the electronics industry, and such additional individuals, as it deems appropriate, as ex-official non-voting members of the Board of Directors."

CEO. The first and most critical activity of the Board will be to appoint the first CEO. This appointee must be an energetic leader with a commitment to implementing "Big M" manufacturing technology that can produce both secure military components and low-cost, high-volume commercial components. An example of such a leader would be Hector Ruiz, the retired CEO of Global Foundries, who has demonstrated leadership and has respect within the industry.

Infrastructure and Membership of the IP-IMI, IP-MCE and IP-MTT

In terms of establishing the critical infrastructure such as IP policy, rules of engagement, and bylaws, the best practices of iNEMI, Sematech, and existing IMIs will be used.

The organizational structures should consist of one HQ and two hub sites: one to focus on chip technology and one to focus on packaging and assembly technology. This dual hub organization is capable of agile and coordinated innovation across the two critical elements of R&D infrastructure. The PSMC has already targeted establishment of a consortium for enabling packaging and assembly technology that is even more critical to low-cost, high volume success than device technology. Key gaps that must be overcome in packaging technology are the development of i) precision assembly equipment and ii) a new generation of test technology for all steps of the manufacturing process.

Membership. We propose to develop a tiered membership, described in the next section, which will emerge as the sustaining support for an independent Integrated Photonics Manufacturing Association. Each member must commit to their participation in terms of both funds and in-kind support. The iNEMI experience has shown that separate commitments on a technical level and a resource level are advisable. Some levels of the tiered membership must commit to send personnel to work at the hub sites.

Activities Taken to Secure Funding

A key responsibility of the CEO and Board of Directors will be to secure matching funding for Phase 2 and total funding for Phase 3. The AMP entities will provide an initial funding foundation. In addition, the IP-IMI, IP-MCE and IP-MTT must secure funding support from a complete "supply-chain" of partners to insure that the technology developed meets the commercial and military requirements for performance, cost, and market entry. Key players in the supply chain must be attracted to use the hub facilities, staff, and educational programs to meet their R&D needs through both pre-competitive R&D

and unique partner programs. The PSMC Phase 1 Roadmap and Technical Planning will stimulate and establish consensus within the supply chain of needs that provide high-payback from funding and in-kind support. This information will be shared with the leadership of the hubs to assist them in developing committed sources of industrial support and funding.

Funding Model. During Phase 2 the MIT Microphotonics Center and iNEMI will conduct their biannual roadmap workshops on integrated photonics based on funding from the IP-IMI. We have responded with estimates for such funding to requests from all of the major participants in the IP-IMI FOA process.

We will participate in building a successful funding model for the IP-IMI that should transfer forward to MCE and MTT entities where we anticipate a leadership role. Significant initial participation and funding from the user community is necessary if any of the entities are to become self-supporting in just five years. Sematech took considerably longer to become self-supporting.

A possible scenario for different classes (tiers) of annual membership for a sustaining entity follows with examples of interested firms.

- Specify system requirements for their applications: \$2 M (Verizon, Facebook, Microsoft, Akamai) (MIT, BU, Carnegie Mellon, Arizona)
- System providers: membership: cash or in-kind equivalent \$1M: establish common platform for next 5-25yrs (Intel, Cisco, IBM, A-L Bell Labs, Luxtera, Infinera, Lockheed-Martin, Raytheon, MACOM, Juniper, ADI...) (MIT, BU, Carnegie Mellon, Arizona)
- Tool and packaging/test technology providers: membership: development platforms: develop solutions to identified Roadblocks (Palomar, IMT, Chiral, Teradyne, Amkor, Brooks Automation...) (MIT, BU, UMass Lowell, UMass Amherst, GaTech, SUNY Binghamton...)
- Chip manufacturers: membership: \$500K or equivalent: specialized tools/designs/personnel to develop next platform modules for chips, packages and connectors. (Luxtera, Finisar, Oclaro, Avago, ADI, JDSU, MACOM, Intel, Cisco, IBM, Infinera...) (MIT, Colorado, UC Berkeley, Stanford, BU,...)
- Fabs: membership: contribute PDK, equivalent value or \$500K: fabricate designs for members (IBM-Burlington VT, Intel NM, Freescale CA, Global Foundries NY, National/TI ME, Fairchild Semiconductor ME) (CNSE, MIT.nano, Sandia, MIT-LL) 4 runs/yr. @ \$500K/run and 3mo/run + 1mo for packaging
- Materials and specialty products: membership: \$500K or equivalent: support entire supply chain projects (3M, Corning, Soitec ...) (MIT, BU, UMass Lowell, UMass Amherst, New Mexico)
- Cost modeling: membership: \$500K or equivalent: evaluate tradeoffs among alternate technologies and sensitivity to volume and yield (all companies, RHK, industry, analysts) (MIT)

PSMC Phase 2 Strategy

Two value points are targeted for this period: i) efficient 'stand up' and operation of the Integrated Photonics Institute for Manufacturing Innovation (IP-IMI) and ii) support of Advanced Manufacturing

Partnership (AMP) 2.0 goals by creation of “Big M” technology research, development and evaluation centers:

- Establishment of an IP-IMI with PSMC providing the Technology Roadmap support. Funded by a five-year grant from the U.S. Government (DoD-AFRL) and matching contributions from industry, states, universities and research institutes.
- Establishment of a new public-private manufacturing research and development infrastructure to support the innovation pipeline, which complements Manufacturing Innovation Institutes at earlier and later technology maturation stages, through the creation of manufacturing centers of excellence (MCEs) and manufacturing technology testbeds (MTTs) to provide a framework that supports manufacturing innovation at different stages of maturity and allows small and medium-sized enterprises to benefit from these investments.

The PSMC in Phase 2 will continue to function as a roadmap and organizer of R&D project consortia in support of the successful funded “winner” of the IP-IMI. These are two functions in which iNEMI and the MIT Microphotonics Center have demonstrated successful outcomes. The MIT Microphotonics Center has published 15 years of editions of the Communication Technology Roadmap, focusing on manufacturing platforms for photonic integration. The results of iNEMI’s roadmapping process are well documented¹. Several of the other NIST AMTech programs have requested support from iNEMI in developing their roadmapping processes. iNEMI has also developed and utilized a successful process for identifying key development needs for electronics manufacturing and establishing supply-chain based industrial Technology Implementation Groups to develop statements of work and conduct precompetitive consortium-based R&D. Using this process during the past twenty years iNEMI has established more than 100 projects with participation from more than 150 firms, universities, research institutes, and NIST. Technology areas that have been addressed include electronic packaging, optoelectronics, high density interconnect, Pb-free soldering, Bromine-free printed circuit board, direct flip-chip attach, electronic testing including boundary scan, development of equipment for board assembly, and next generation power supplies. Many of these projects have included development of reliability data and recommendations for industry standards. iNEMI staff has facilitated not only the development of the teams and their statements of work, but also the project management function.

PSMC’s Organization and Funding During Phase 2

Funding. PSMC has notified all organizations competing for the IP-IMI of our willingness to perform the roadmap, project development and execution functions during our Phase 2. The scope of these activities is defined in the following paragraph. We have provided each competitor a preliminary budget of the expenses to perform these functions.

¹ [The Flexible Electronics Opportunity, National Academies Press](#)

Organization. PSMC has established its Executive Advisory Board (EAB). This executive group is responsible for leading and guiding PSMC through Phases 1-3. The Board consists of recognized leaders from industry, research institutes, and key stakeholder organizations. The EAB is responsible for developing and reviewing technical goals, plans and commitments to the evolving AMP manufacturing ecosystem. In that role, the EAB plays a de-facto advisory role to all engaged AMP partner entities.

PSMC Responsibilities during Phase 2

Roadmap. The PSMC for Roadmap objectives for Phase 2 are:

- Create an industry needs-focused Integrated Photonics Roadmap for the next decade by drawing upon the expertise of a broad cross-section of individuals from industry, academia, and government. The results of this work will be available to the electronics industry worldwide. This roadmap will be refreshed on a regular basis as technology evolves and the market responds.
- Identify the major areas on which the iNEMI-MIT PSMC will focus based on definition of system requirements, TWG participation, and economic impact.
- Conduct a gap analysis of these major areas that identifies the challenges and opportunities facing the industry.
- Create rolling 5-10-15-25 year plans for the major areas that identify the projects and activities deemed necessary to close the identified gaps. These plans will become the basis for the formation of the Integrated Photonics Manufacturing projects.

This roadmap process is a bottoms-up “Delphi process” relying on numerous technology experts to give their consensus vision of the technologies that are required to meet their view of future products. The roadmap process does not explicitly identify disruptive technologies, but by identifying needs, particularly those for which there are no known solutions that meet the performance and cost requirements, the members of the PSMC TWGs will implicitly identify areas for innovation and the utilization of disruptive technologies. The full electronics manufacturing supply chain and its R&D institutions will be stakeholders in the process. Existing vital links to twelve roadmap organizations will be maintained: ITRS, OIDA, TPCA, IPC, EIPC, INSIC, IEEE-CPMT, SMTA, ECA, IMAPS, MEMS Industry Group, and PSMA.

Project Development and Execution. The experiences of Sematech and iNEMI have shown the need to develop a strategic plan with key milestones that address the “red brick walls” that cannot be crossed without industry collaboration. To achieve the ultimate goal of low-cost, high-volume manufacturing the Project Development and Execution activity must be a collaborative function that develops consensus within the stakeholder community of the preferred technology direction. PSMC participants have many years of experience in developing collaboration and industrial support. PSMC also has experience in project management and cost modeling of product emulators to insure that the enabling technology being developed is consistent with the volume and cost goals. For a number of years, iNEMI and MIT-MphC have been managing industry collaborations and have developed solid methodologies to plan and execute R&D programs. The elements of that process include:

- Attracting industrial partners across the supply chain,

- Developing a Statement of Work (SOW) for each effort that details the resources needed by task/activity,
- Holding Bi-Weekly conference calls on a set schedule that review status to plan and assign actions to address issues identified. All critical participants are expected to attend.

Key Organizational and Technical Milestones

The Appendix of Key Milestones is a preliminary list some of the events which must occur during Phase 2 to insure:

- Meeting the identified needs for R&D knowledge in both semiconductor chip fabrication, packaging and system assembly technology;
- Quickly producing technology demonstrators;
- Strongly coupled Research, Manufacturing and Development;
- Evaluating the reliability of the new materials and processes;
- Achieving low volume production;
- Achieving high-volume, low-cost objectives;
- Establishing a record of success and sufficient support from industry to become self-funded in five years.

Phase 3: Integrated Photonics Manufacturing Ecosystem; beyond AMP 2.0; and Sustainable Self-Sufficiency: July 2020-2035

Overview

During this period PSMC will coordinate the establishment of an industry led, self-sustaining R, D&M manufacturing infrastructure and ecosystem from the IP-IMI, IP-MCE and IP-MTT foundation. Establishment of a cooperating and coordinated end-to-end supply chain will be the gating and sustaining activity for this enterprise. Adoption of common manufacturing platforms for cost effective, high volume manufacturing is dependent on projection of i) a >15 year life of the platform and ii) a scalability of performance/cost under a common learning curve. As PSMC stated in its proposal, given the strong and growing markets for Integrated Photonics, we must implement strategies that ensure the sustainability of the research and development programs beyond Phases 1 & 2.

Success in Phase 2 will be measured by the extent of implementation of the R, D&M project results. Significant adoption of the project results in the manufacturing supply chain Roadmap and products should create a strong US-centric supply chain that will lead to a stream of industrial funding that will sustain manufacturing growth and the AMP hub ecosystem that support them. These funds are typically in the form of grants or fees for development services from the industry, government, and academic institutions. The AMP hubs will continue to provide support for training and education of needed skills that will be sustained by direct company funding of classroom, internship and apprentice activities.

The sustainability model for roadmap and technical planning for Phase 3 is that PSMC will continue to research and release the Roadmap for component, materials and system technology needs; the packaging roadmap will continue to be a joint PSMC-ITRS-iNEMI activity; and the integrated photonics

technology roadmap will merge with the ITRS semiconductor roadmap. The Project Development and Execution function of PSMC would transfer to the IP-IMI, IP-MCEs and IP-MTTs at the end of Phase 2.

Key Milestones.

The Appendix provides an initial list of key milestones for Phase 3. It is essential that commercial Integrated Photonics Systems be based on a high volume, low cost manufacturing platform by 2021 to attract funding to support the performance/cost scaling learning curve. One of the first areas of focus for the self-supporting organization will be developing the enabling technology for photonic switching. Phase 1 and phase 2 milestones are also included for completeness.

Appendix: Key Milestones for each Phase

Table 1. Key Milestones for PSMC Phase 1

	2014						2015												
	Q1			Q2			Q3			Q4			Q5			Q6			
	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Stage 1 Roadmapping																			
Update Plans & Start																			
Roadmap Mfg. Needs																			
Roadmap Sys. Needs																			
Stakeholder Review																			
Survey Results																			
SC Modeling																			
Cost Modeling																			
Sustainability Plan																			
Stage 2 Emulator Dev.																			
Design Emulator																			
Dev. Emulator Attributes																			
Stakeholder Review																			
SC Modeling																			
Cost Modeling																			
Stage 3 Technical Plan																			
Prioritize projects																			
Develop SOWs																			
Complete Model Dev.																			
Stakeholder Review																			
Start Pilot Project																			
Final Report																			
Quarterly Reports																			

Table 2. Key Milestones for IP-IMI: Phase 2

	2015		2016				2017				2018				2019				2020		
Phase 2 Key Milestones by Quarter	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
Establish BoD, Leadership Team	Yellow																				
Establish IP, Initial Membership, Operating Procedures, etc.		Yellow																			
Establish Technical Committee		Yellow																			
Initial Development Projects		Green: Packaging																			
Initial Research Projects		Green: Silicon PDK																			
Begin Educational, Training Programs				Orange																	
2nd Phase R&D Projects					Green	Green	Green	Green													
First Working Technology Demonstrators					Blue																
Qualification of New Materials						Purple															
Initial Prototype Mfg. Equipment						Red															
Application of Technology To Prototype Products								Blue													
Reliability Qualification of New Technology										Red											
First Component Manufacturing for Military Product													Green								
R&D on Photonics Switching Manufacturing													Green	Green	Green	Green	Green	Green	Green	Green	Green
First Photonic Systems Manufacturing														Green							
Medium Volume Production																Green					
Begin Phase 3 Funding Model																		Yellow	Yellow	Yellow	Yellow
Achieve Five Year Cost Objectives																					Green

Table 3. Key Milestones for IP-IMI: Phase 3

	2020		2021				2022				2023				2024				2025		
Phase 3 Key Milestones by Quarter	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	
Funding by Industry, & Research Org for Development and Prototype Fabs and Packaging Facilities																					
Members Achieve High Volume Commercial System Production																					
Members begin Photonic Switching Manufacturing																					
Members Achieve Low Cost Objective																					