Innovation to Impact: Observations

Guru Parulkar
Stanford University
Open Networking Foundation

parulkar@stanford.edu

Proposed Objective of the Talk

Prototype
Publications

Innovation

?

Impact

$B Product
$10-$100B Industry
Societal Impact
How we live: work, play, learn

- Is there a science to it? If yes what is it?
- Are there lessons we can learn from previous experiences?
- Can we replicate in future, in different geographies, different countries?

Is there science to happiness? Can we replicate it?

Very very difficult to answer! I can make a few observations based on my experience

Yes Stanford University and its people have an excellent track record

Stanford University

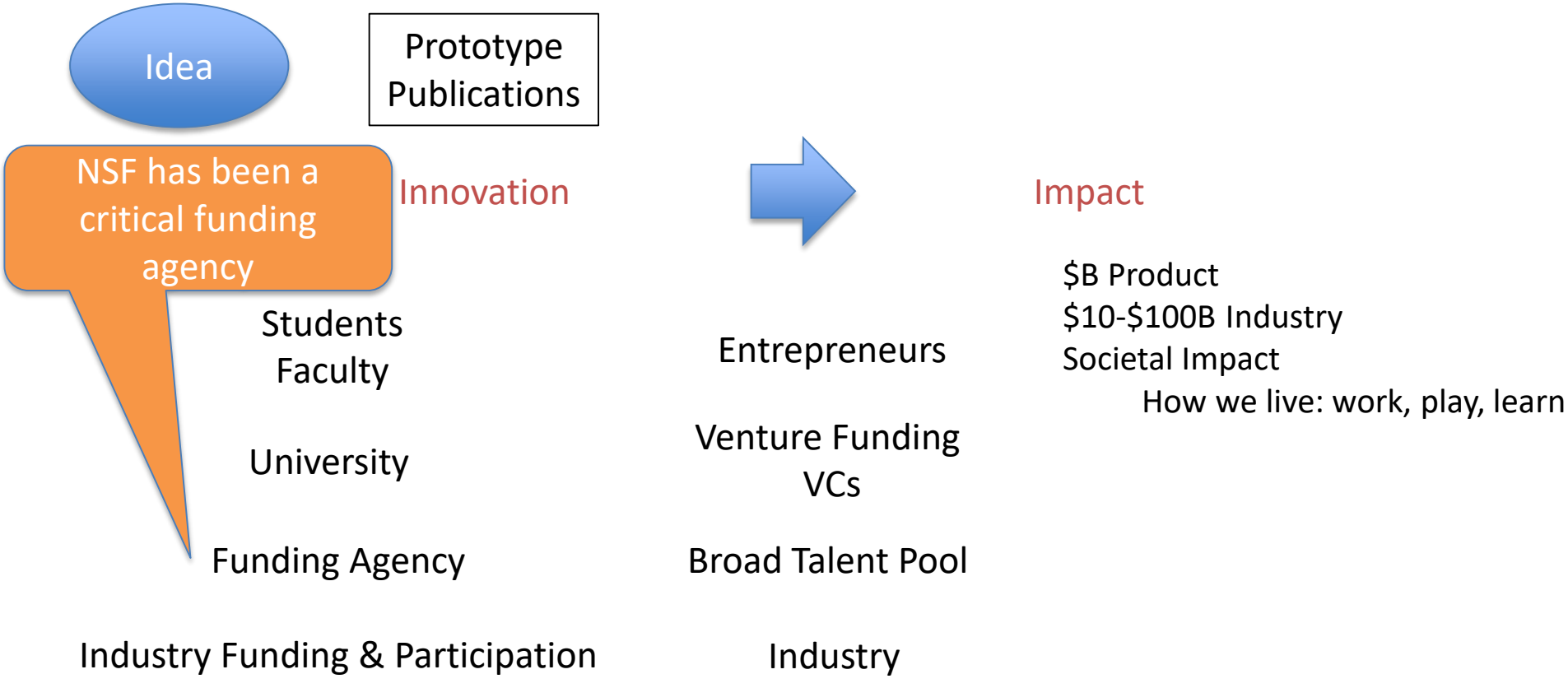
HP
Google
Cisco
Sun Microsystems
Silicon Graphics
Netflix

Many many more

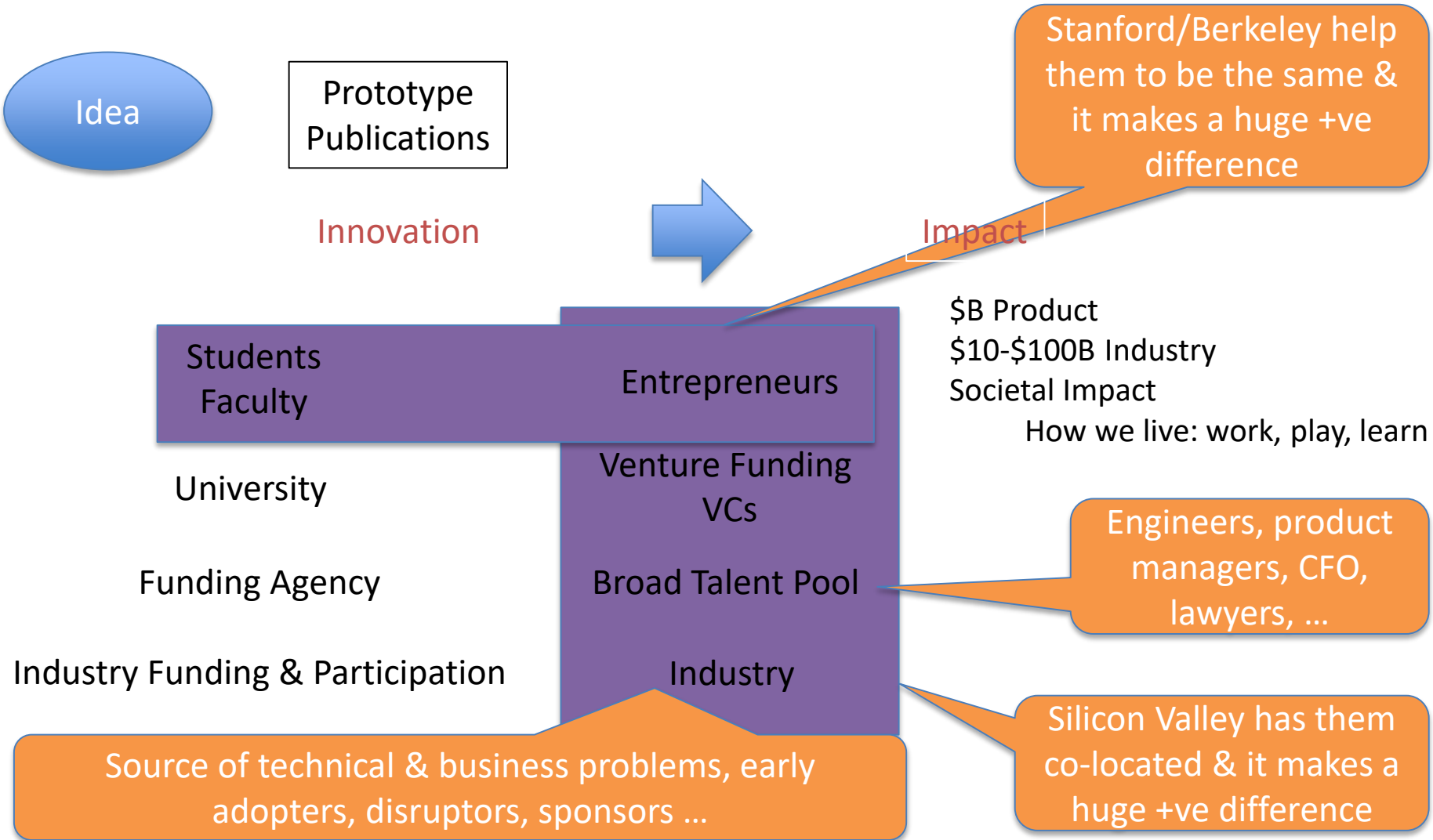
- Stanford is an important part of Silicon Valley with even a bigger track record
- It is a complex ecosystem with a long history and a subject of many studies
  - Broad observations and lessons to learn
  - Many theories… Not something that can be easily replicated

I am a very insignificant participant and observer so don't take my comments too seriously…

Key Participants and Ingredients



Silicon Valley Success Factors



Questions

- What role students and faculty play?
- What role do funding agencies play? How can they be effective?
- How does Stanford help students and faculty be successful entrepreneurs as well?
- How does industry help (and slow down) disruptive innovations?
- What does it really take to turn an innovation into real impact?

Questions and Answers

- What role students and faculty play?
  - They are the creators of the vision as well as technologies/inventions
  - They have the passion and conviction to drive their vision and creations to success and so it is really important for them to be entrepreneurs too
- What role do funding agencies play? How can they be effective?
  - NSF has been playing a very important role as a funding agency
  - Some times its standard processes don't work and the leadership has to enable "disruptive innovation" in its own operation
- How does Stanford help students & faculty be successful entrepreneurs as well?
  - Long history and expertise: entrepreneurship is in the DNA or in the air
  - Put focus on doing the right thing and creating a real impact
  - Help students and faculty be successful and not come in the way with inflexible policies
- How does the industry help (and slow down) disruptive innovations?
  - It is a source of funding, the next big challenge, talent pool, early adopters, …
  - Have to recognize incumbents who don't like disruptive innovations & lot to learn from them

Questions and Answers

- What does it really take to turn an innovation into real impact?
  - It takes too much effort beyond building the first research prototype and publishing papers
  - 10-15 years of sustained effort: funding, students, staff, …
  - Research, prototypes
  - Open source platforms and solutions
  - Research ecosystem: enable other universities to use and build on
  - Create startups to drive your vision and technology to real use and impact
  - Industry ecosystem to standardize and adopt with many phases: lab trial, field trial and then production deployment
  - And more

There are many uncertainties and unforeseen barriers to overcome

Finally it takes “luck” – not clear why an idea succeeds and others fail

Innovation to Impact: Observations

Details…

My Own Experience: Participant & Observer

ATM and Fast Packet Switching
Washington University
1987 -- 2001

Growth Networks
Cisco, Bay Networks, Nortel, …

ATM: $50B+ industry at its peak
Fast packet switching continues to play a role in networking

Software Defined Networking
Stanford University
2007 -- Present

Nicira
Big Switch
Foreword
Barefoot
…

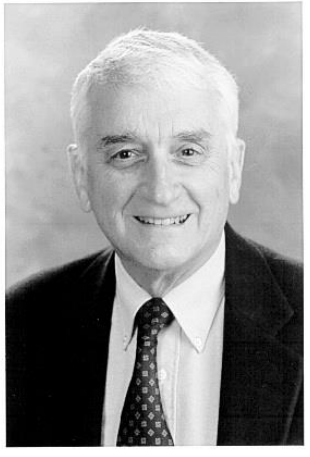
Some project SDN to be a $150B+ market in few years

Even networking is a big complex ecosystem and not easy to derive broadly applicable lessons

So again don't take my comments too seriously…

Fast Packet Switching and ATM: People
Washington University 1985 - 2000

Jon Turner
Junior Faculty in 1985
A grand vision, strong conviction
Amazing technical expertise (theory, algorithms, VLSI, software systems)
Bell Lab experience, Leadership



Jerry Cox
Department Chair
Amazing technical depth & breadth
Lot of experience with disruptive innovations
A great leader

Students (30+), faculty (3-5), staff (15+) that contributed to 2-3 generations of systems over 15 years: Multiple ASICs, Switches, Host NICs, Control Software, Apps, Deployments

Funding Agencies

- NSF
  - Multiple grants
  - Five year large grant and several smaller grants
  - Access to MOSIS ASIC fabrication facility
  - Infrastructure grant to build gigabit kits and distribute to other universities: ATM switches, NICs, software to build gigabit ATM networks

  NSF was growing its investment in networking; Washington Univ was well placed
- DARPA
  - A couple of large grants to build gigabit technologies and apps
- Industry Consortium – Breakup of AT&T in 1982 provided the key impetus
  - Southwestern Bell Telephone Company, Bell Core, NTT, BNR
  - Vendors: NEC, Fujitsu, Bay Networks, Nortel, ….

Washington University and St. Louis

- Washington Univ great place to do research
- It is not that good for entrepreneurship and starting companies
  - Approach to licensing intellectual property: get the best deal at the front end
  - Very conservative approach to Conflict of Interest – simply avoid it
  - Didn't know how to support faculty and students as entrepreneurs
- St. Louis didn't have
  - Telecom or Internet industry (except Southwestern Bell & that also moved to Texas)
  - A history and culture of high tech startups

  A serious limitation to create real industry impact

- This meant doing Growth Networks in Silicon Valley

This becomes a self perpetuating reality and breaking it is a huge challenge for many cities and geographies

Impact

- Washington University contributed to creation of ATM/B-ISDN, fast packet switching, MPLS, …
- Technology transfer to many vendors and operators
- Growth Networks – packet switching for Cisco's flagship routers
- Impact was compromised due to location
  - Too much emphasis on telecom operators and not enough on Internet
  - Ecosystem
  - Growth Networks delayed by a year

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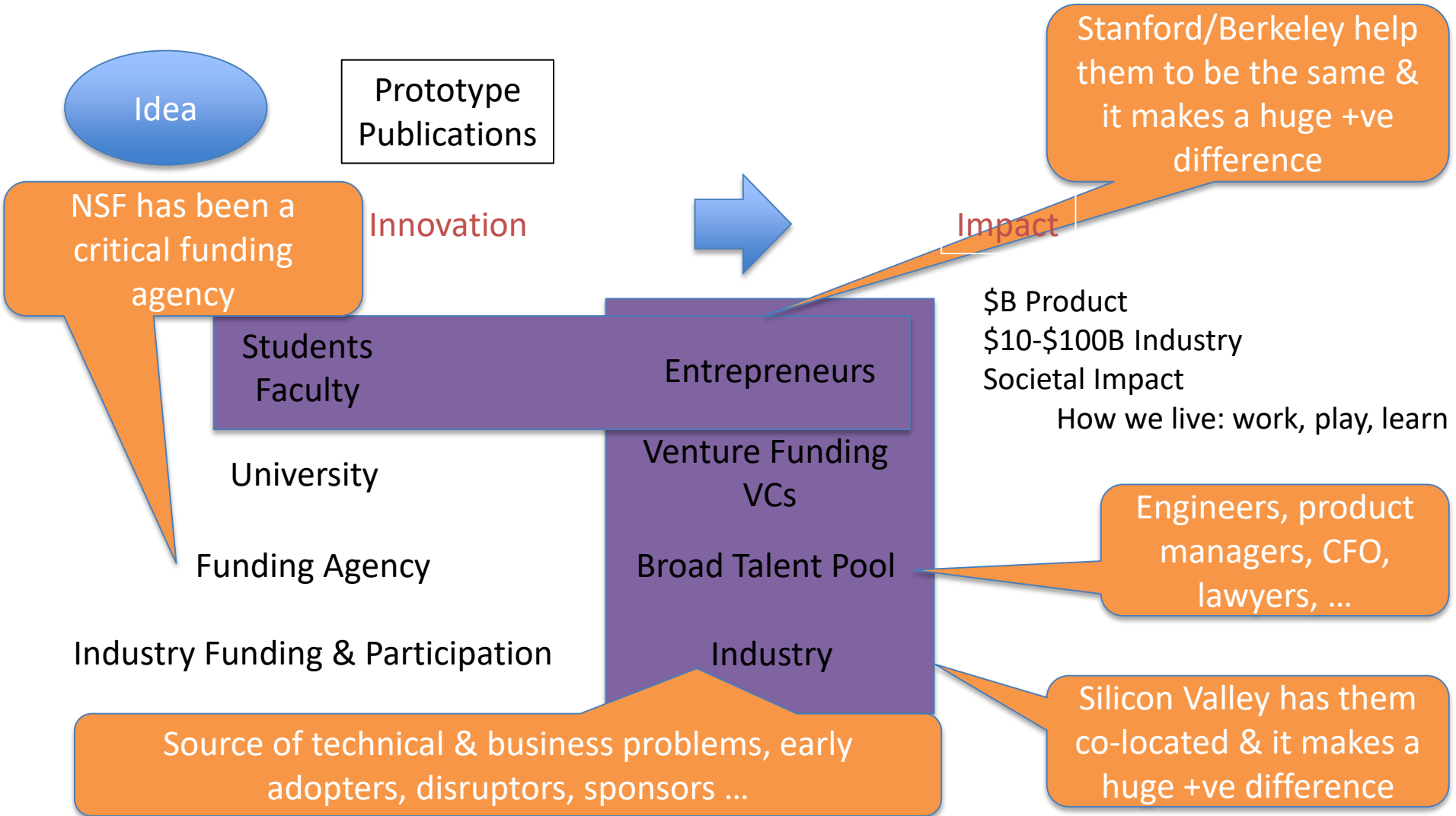


SDN and Key People

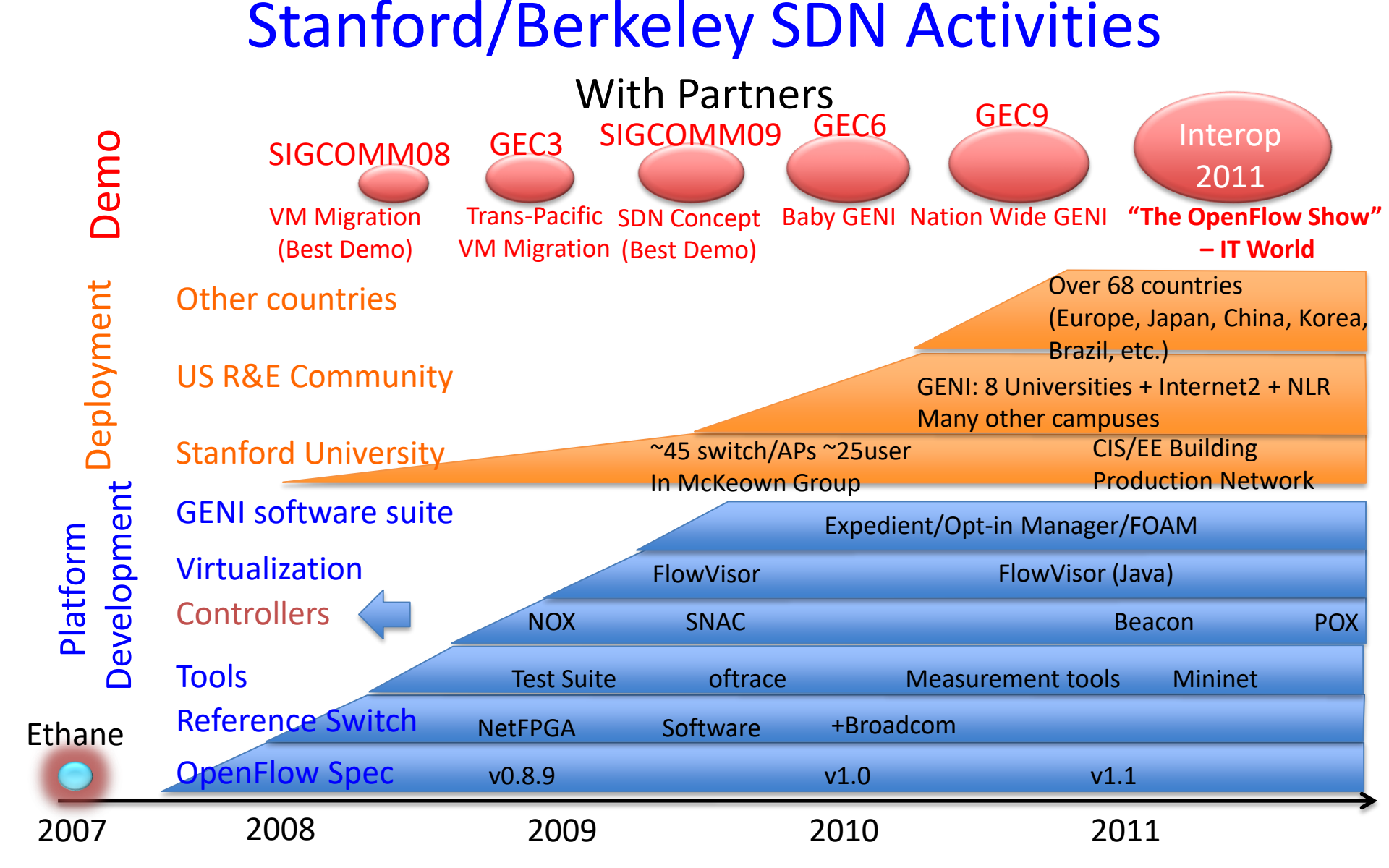
Nick McKeown
Professor, Stanford

Martin Casado
PhD from Stanford

Scott Shenker
Professor, UC Berkeley

- Combination of entrepreneurship, technical depth and breadth and deep understanding of the industry played an important role
  - Focus on network innovation with disaggregation and programmability as opposed to focus on reinventing the protocol stack
- Several other faculty, students, staff have been contributing to success of SDN
  - At Stanford and at other universities (especially Berkeley, Princeton, Cornell, …)
  - Multiple batches of students

Stanford/Berkeley SDN Activities



Stanford SDN Startups

Founded during 2007 -- 2013

Silicon Valley based founders, VCs, leadership teams, local early adopters, …

- Nicira (by Martin, Nick and Scott)
  - Acquired by VMWare
  - Leads SDN for datacenter network virtualization
- Big Switch Networks
  - SDN for enterprise datacenters
- Forward Networks
  - Network debugging and verification
- Barefoot
  - Switching silicon with programmable forwarding
- …
- [There are many other SDN startups]

Silicon Valley provides VC funding, talent pool, and industry ecosystem

Other Organizations Founded to Realize SDN 2011-2012

ONRC
ON.LAB

Build strong intellectual foundation
Bring open source SDN tools/platforms to community

Standardize OpenFlow and promote SDN
150+ Members from all parts of the industry

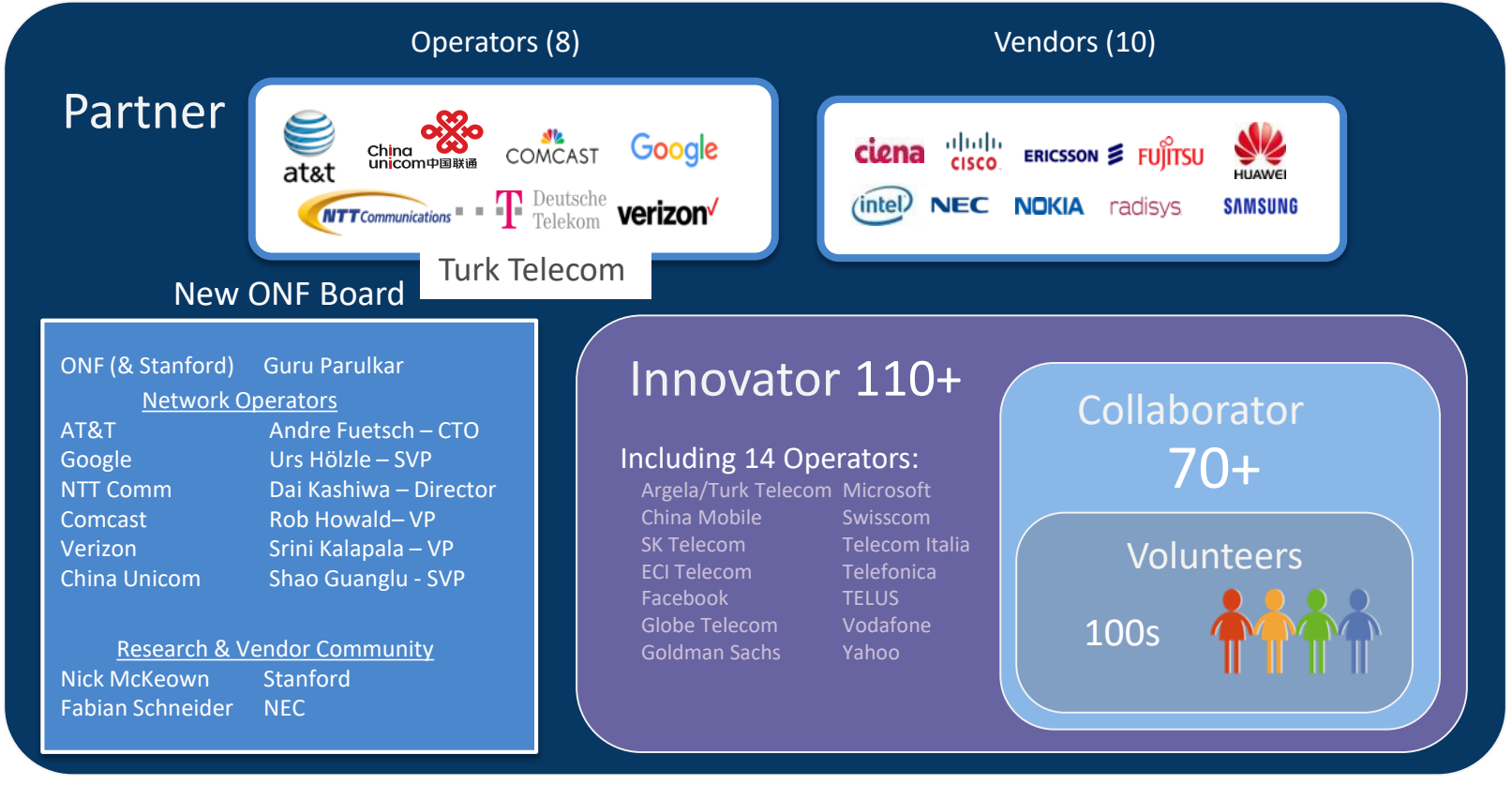
Bring best SDN content; facilitate high quality dialogue
5 successful growing events; participation of ecosys

SDN Academy

Bring best SDN training to companies
to accelerate SDN development and adoption

The ONF Ecosystem – 200+ Members Strong

Vibrant Operator Led Consortium Positioned for Success



Results of Service Provider and ONF Partnership

- Device disaggregation for all key service provider domains
  - Packet switches, mobile eNBs and RAN, ROADMs, …
- Open source software building blocks
  - ONOS: SDN control & config platform with scale, performance, HA
  - Trellis: SDN based leaf-spine fabric for central offices and datacenters
  - XOS: Platform for service/VNF management and composition
- Disruptive Solutions
  - CORD for residential (wired: R-CORD), mobile (4G, 5G: M-CORD), and enterprise (E-CORD) customers
  - Packet-optical backbone with SDN control and disaggregated ROADMs

Service Provider Traction for ONF Platforms and Solutions

North America

- **AT&T:** R-CORD, M-CORD (Multi-Service Edge), vOLTHA
- **Verizon: M-CORD**
- **Sprint:** M-CORD
- **Comcast:** R-CORD
- **CenturyLink:** R-CORD
- **Google:** Multi-access CORD

Asia & Australia

- **China Unicom: M-CORD, E-CORD**
- **China Mobile: M-CORD and E-CORD**
- **NTT, NTT East: IP+Optical, R-CORD**
- **SK Telecom: M-CORD**
- **Telstra: M-CORD**
- **Reliance Jio: M-CORD**

Europe

- **Deutsche Telekom: R+M-CORD (Hybrid CORD)**
- **Telefonica: R-CORD, M-CORD**
- **Telecom Italia: M-CORD**
- **Colt: R-CORD**
- **Turk Telekom/Netsia: M-CORD & ONOS SDN Control**

Interest continues to grow on a monthly basis.

Many successful POCs and lab trials and a few field trials

Research Funding

- NSF
  - Two five year large grants and a few smaller grants
  - NSF Expedition Program
    - Programmable Open Mobile Internet of 2020 (POMI2020)
  - Future Internet Architecture (FIA*)
    - Architect for Innovation
  - A large GENI infrastructure grant
    - Build enterprise GENI kits, distribute to other universities and build a nation-wide SDN network
- NSF Funding: played a very important role in enabling SDN, but
  - Peer review and standard processes declined all three major proposals on SDN (including FIA) and were rescued by the CISE leadership
- Significant industry funding by Stanford Clean Slate Program

Role of Stanford University

As per its history and track record, Stanford

- Enables students, faculty and staff to be entrepreneurs as well
- Knows how to focus on what is right and create impact
- Knows how to manage COI
  - Rather than simply avoid COI, it is important to manage it
- Is not committed to extracting value from startups at the front end of the deal when it is not clear if a start up will be successful or how successful
  - Too many universities get stuck in this process

In general Univ focuses on how it can help students and faculty be successful rather than enforcing some arbitrary policies

Innovation to Impact: Observations

Summary

Silicon Valley Success Factors