Indian Institute of Technology Mandi

Scaling the Heights

Curriculum Innovation for Design Engineers

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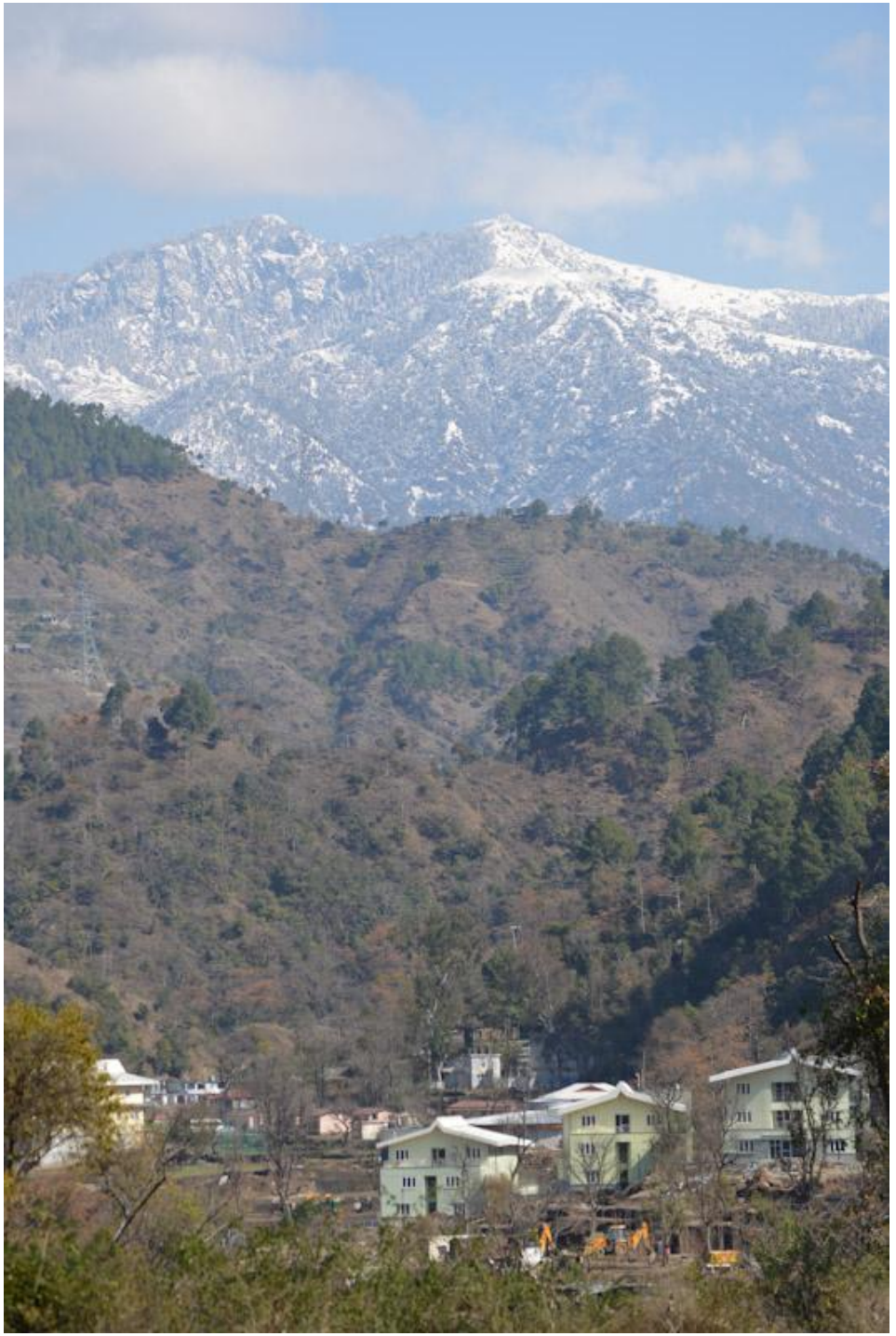
Outline

- *Need for innovation for India's tomorrow*
- *Evolution of engineering*
- *BTech curriculum for design and innovation*
- *Conclusions*



Services vs Intellectual Property

- *Manufacturing and services: earnings proportional to effort*

➔*linear growth (e.g. Infosys, TCS, Maruti…)*

- *IP: one time effort for design, earnings thereafter with minimal effort*

➔*exponential growth possible (e.g. Google, Microsoft…)*

Service vs IP

- *IT services @Rs.10 lakhs/person-yr:*

  2 lakh programmers/operators = Rs.20,000 cr/yr

- *IP on 2G cellphones @3% royalty:*

  200m cellphones/yr = Rs.1,800 cr/yr

- *IP on 4G cellphones @15%:*

  200m cellphones/yr = Rs.24,000 cr/yr

IP created by a few 100 engineers

Prosperity for all Indians in a short time requires exponential growth

➔*need ownership of IP*

➔*need engineers who can make India the Design House for the world*

Evolution of Engineering

The Middle Ages to early 20th century, design as an art:

- *Leonardo da Vinci*
  - *Italian polymath: artist, sculptor, painter, engineer, inventor…*

- *Robert Fulton*
  - *American artist, mechanical inventions as a hobby*
  - *First commercially successful steamboat*
- *Samuel Morse*
  - *painter until age 34*
  - *turned to long distance communication when wife died*
  - *co-inventor of telegraph and Morse code*

Engineering Education

- *Engineer as an artisan*
- *Apprenticeship to acquire skills and experience of a master*
- *Development of handbooks with numerical tables, designs, rules of thumb*

Engineering and World War II

- *Pre-WW-II, lip-service to science to give respectability*
- *During WW-II, true science base grew*
  - *Development of radar, sonar, radio*
  - *Encryption and code-breaking*
  - *Operations research for logistics*
  - *…*

Education Post WW-II

- *Strong push towards science-based engineering curriculum, especially in US*
- *Driven by MIT, Stanford and other research Universities*
- *Spurred by generous funding from US Government (Military and NSF)*
- *Maths-based (analytic) courses gained higher status than design-based (synthesis) courses*
- *Dependence on computer simulation/design without understanding its limitations*
- *Japan, Germany and Netherlands retained strong emphasis on practice*

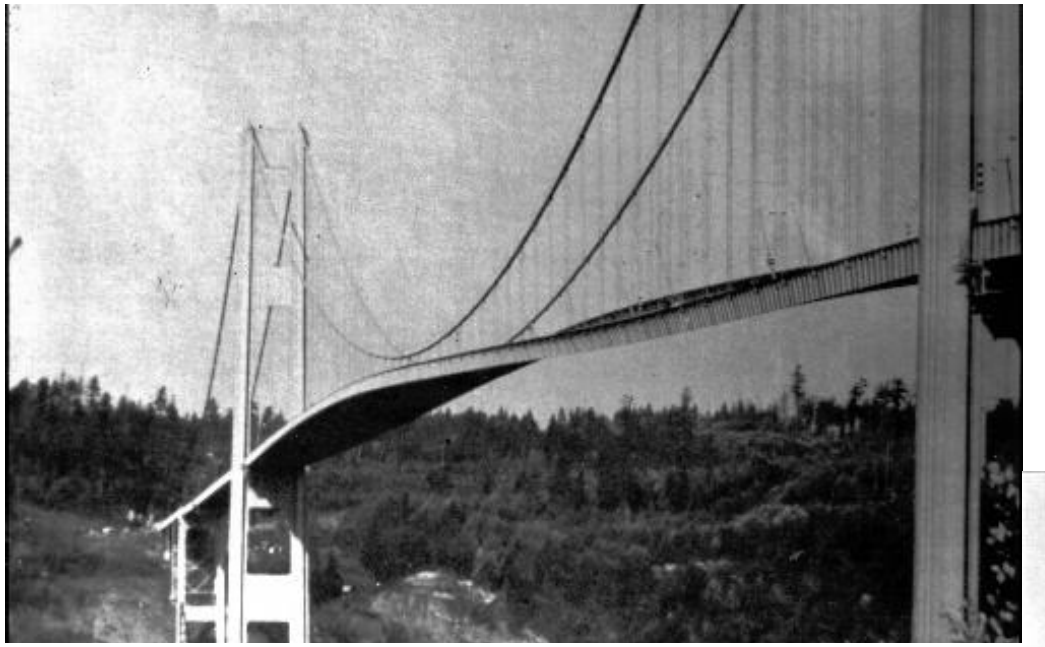
Successes

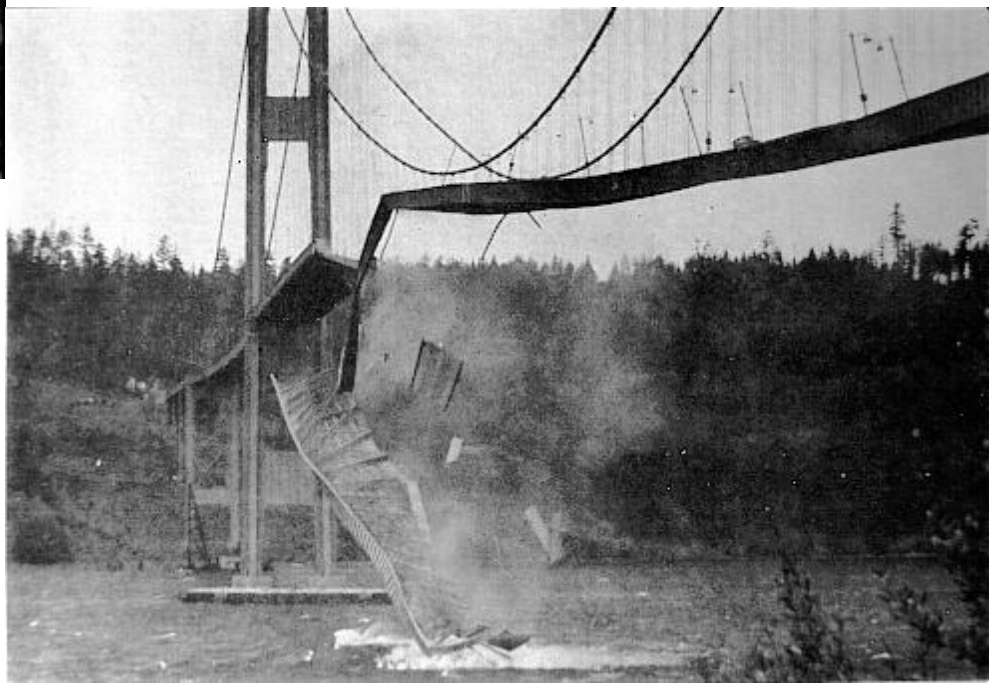
Failures

Space Shuttle

Challenger Space Shuttle explosion:
failure of an O-ring seal

… Failures





Tacoma Narrows Bridge: *collapsed due to a modest 70 kmph crosswind*

http://www.enm.bris.ac.uk/anm/tacoma/tacoma.html

Technology Ups and Downs

- *Cause of these spectacular failures: design flaws that could easily have been avoided*
- *Successful design requires a judicious mix of science, computation and hands-on experience*

The Pendulum Swings Back

- *Shift back to including design in engineering education*
- *Conceive-design-implement-operate (CDIO) initiative in UG education, by MIT*
- *Incubation of technology product companies by IIT Madras since 1992*

  - >200 startups by IITM faculty, students

  - students work on industry projects
- *Design & Innovation curriculum in IIT Mandi BTech*

Innovation at IIT Mandi

Teaching and research culture to foster Design & Innovation

… at IIT Mandi

Inter-disciplinary culture in teaching & research

Unique Design-oriented B.Tech. curriculum

Practicum: Practice before theory

Self-motivated students learn on their own, become leaders

Others appreciate theory when it is taught later

Design & Innovation Stream in B.Tech.

- *Inter-disciplinary teams with assigned partners*
- *Systematic, documented working including*
  - *Problem definition*
  - *Demo of working product/prototype*
  - *Weekly reviews with minutes of meetings*

Innovation Stream in B.Tech.

Year 1: Reverse engineering

- *Random, inter-disciplinary teams*
- *Study existing products, eg. Fan, toaster, …*
- *Disassemble and document its design*
- *Reassemble*

Year 2: Design practicum

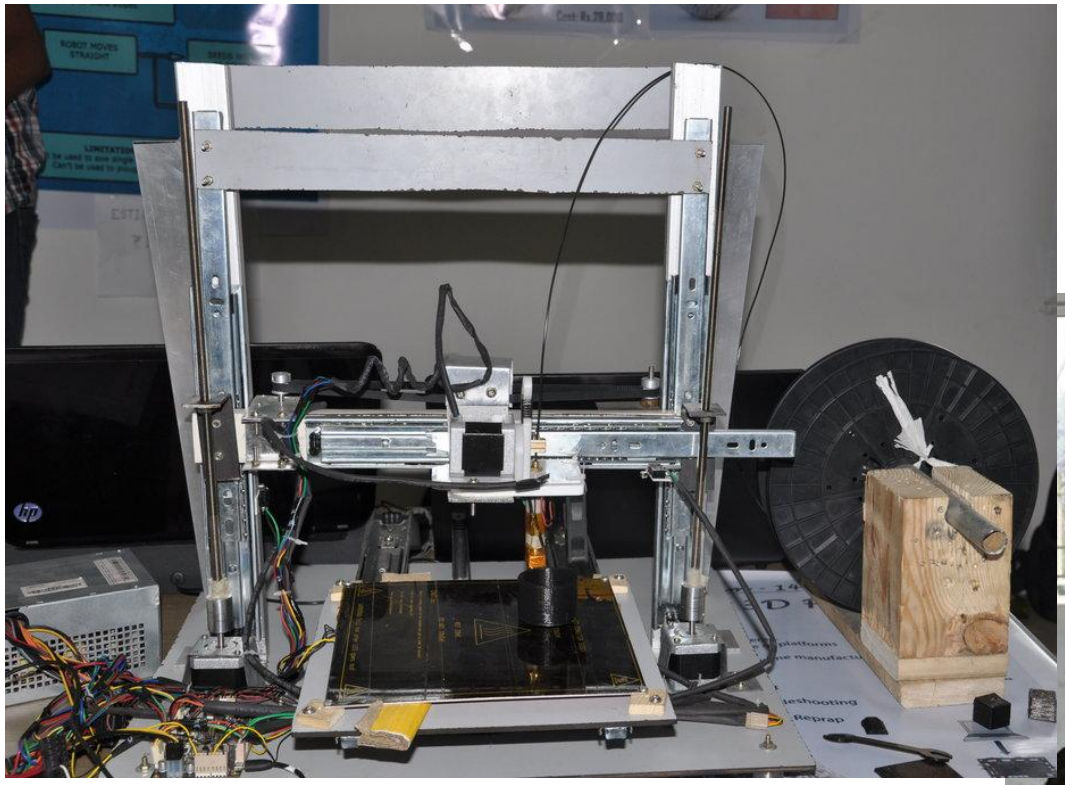
- *Practice before theory*
- *Design and build prototype product for real-world problem*
- *Random, inter-disciplinary teams*

Projects by 2nd B.Tech. students

- *Temperature-controlled magnetic liquid stirrer for research labs*
- *Voice-controlled wheelchair for quadraplegics*
- *Cellphone charger driven by leg while walking*
- *Drip irrigation system* →

… Year 2: Design practicum

Low-cost 3D printer, gas-leak detector, smart board, clothes drier, *oil-spill remover*, …



Yr 3: Socio-Technical Practicum

3rd BTech Practicum

Projects on social impact of technology, market research

15-25 UG students from WPI, US resident in Kamand for 3 months/year

- *Direct solar lighting for village houses*
- *Quality of milk*
- *Irrigation in the Himalayas*
- *Hill farm mechanisation*
- *Womens education*
- *…*

Water Bottle Solar Light

Year 4: Major technical project

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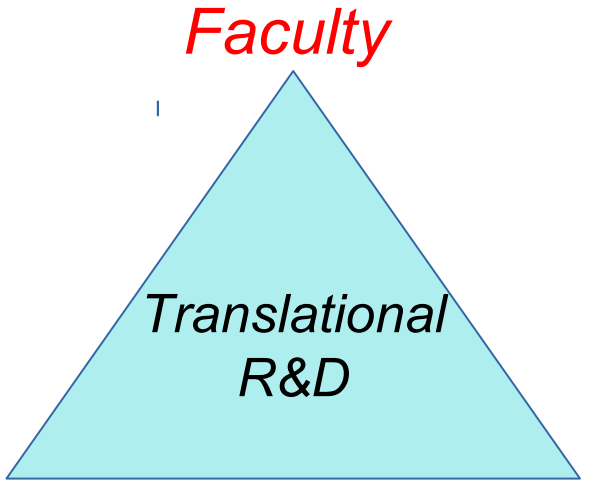
- Capstone of the 4-year programme
- Major technical contribution in the discipline
- Individual or self-chosen team

Industry Interactions

- *Industry engineers as guest/adjunct faculty*
- *Industry-sponsored research projects*
  - *Applied product-oriented R&D with deliverables*
  - *Flexible IPR agreements to suit the needs*
- *Entrepreneurship*
  - *Virtual student companies, IIT as the customer*



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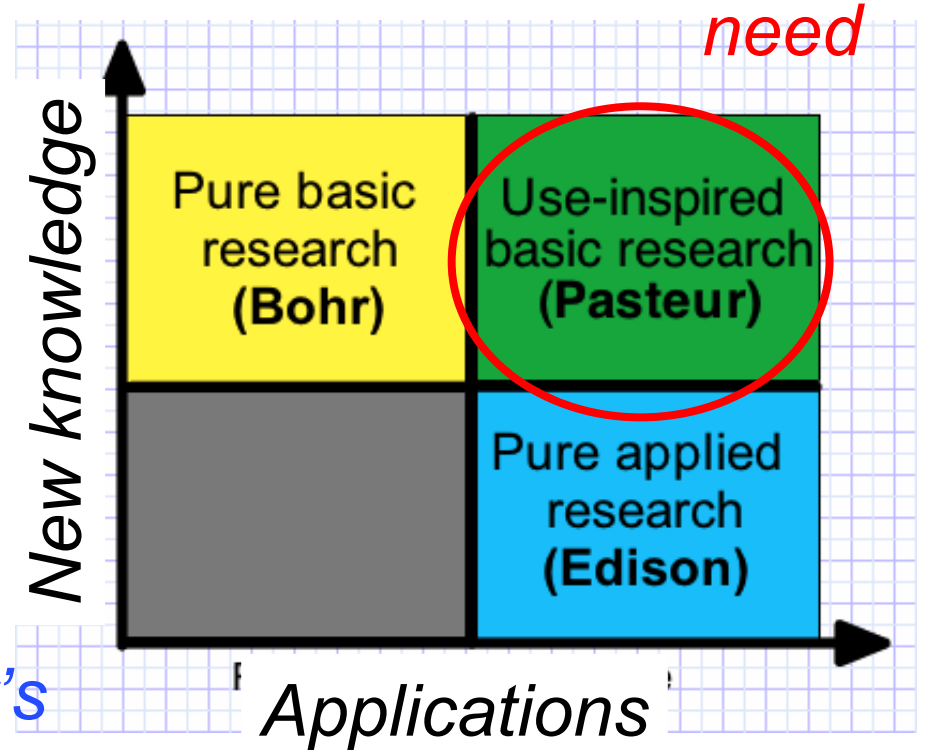
Outcomes at IIT Mandi

- IIT Mandi web-site designed by 1st B.Tech. students, run by them from 2010-2015
- Online Faculty Application portal designed and run by 2nd B.Tech. students, used for 6 years
  - Used by some other institutions
- Competitive successes
  - Pradeep Seervi, 1st in GATE(EE) 2015, Aather Khan 2nd in Civil Services in 2015, Nitesh Kumar, Gold in Int'l Parabadminton
- Placements
  - Microsoft, Amazon, Infosys, Nucleus Software, Samsung, DRDO, HPCL, Tata Motors, …
  - Universities: CMU, Toronto, Penn State, Georgia Tech, IITs, TU-Munich, …
- Start-ups
  - IITians Tech (2014), The Solar Labs (2017), Kriger Campus (2018)

Conclusions

- *Prosperity for all Indians requires design by Indian engineers*
- *Design is an art, acquired by teaching+learning combo*
- *We have taken the first steps, results promising*

India's need



Pasteur's Quadrant

Links

W. Brian Arthur, *The Nature of Technology: What it is and how it evolves*, 2009

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Johnson, S., *Where Good Ideas Come From: the natural history of innovation*, Penguin, 2010

http://www.iitmandi.ac.in

http://www.tenet.res.in

http://www.cdio.org