Optical links for LHC: experience from the CMS project and future prospects

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- Optoelectronics for LHC
- Lessons learned
- Future trends

Optoelectronics for LHC

- **LCH**
  - 100k point to point links @ 0.5Gb/s
    - 50Tb/s = 4000 pb/day capacity
  - 30M$/10yrs
- **World**
  - 1k fibres in/out of a large city
    - 5% lit at 500Gb/s
    - 2000 pb/day capacity
  - 1000 pb/day worldwide internet traffic
  - 2000M$/yr component market

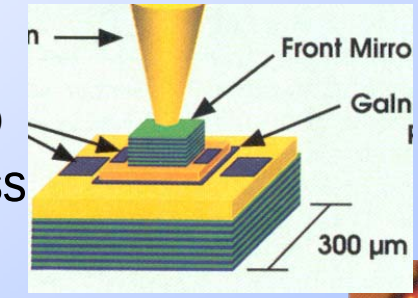
- Are we different?

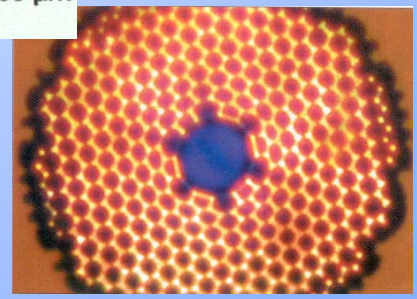
Specificities of LHC program

- Environmental
  - Particle flux, B-field, Material budget, confined space
- Technical
  - Application driven specifications
- Organizational
  - Global collaborative model, Not-for-profit organization
- Commercial
  - Multi-national public money

Environmental specificity

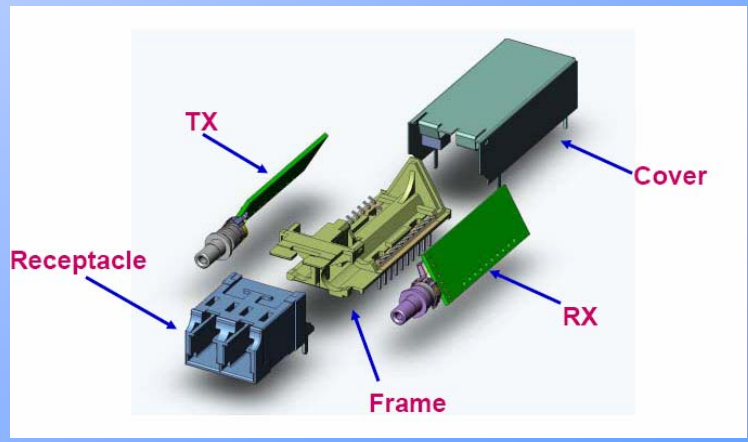
- Particle flux
  - Small active area
    - MQW, VCSEL, QD
  - Undoped, pure glass
    - PSC, air-core





- B-field
  - Non-magnetic materials
    - Cu-Be, ceramic, resins
    - Wire-bond free

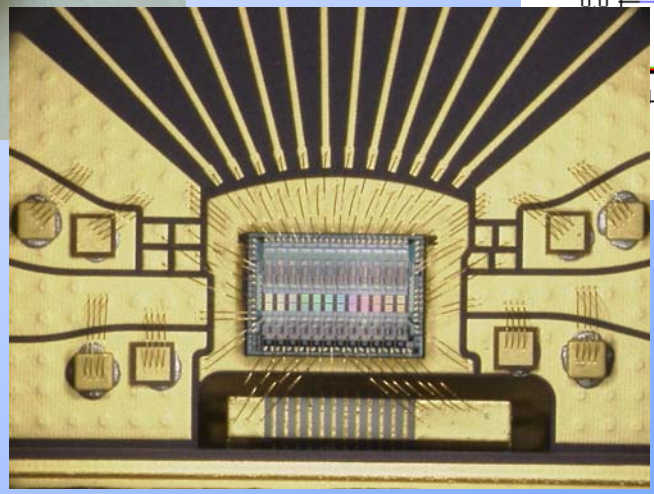
- Material budget
  - Trade-off against ruggedness

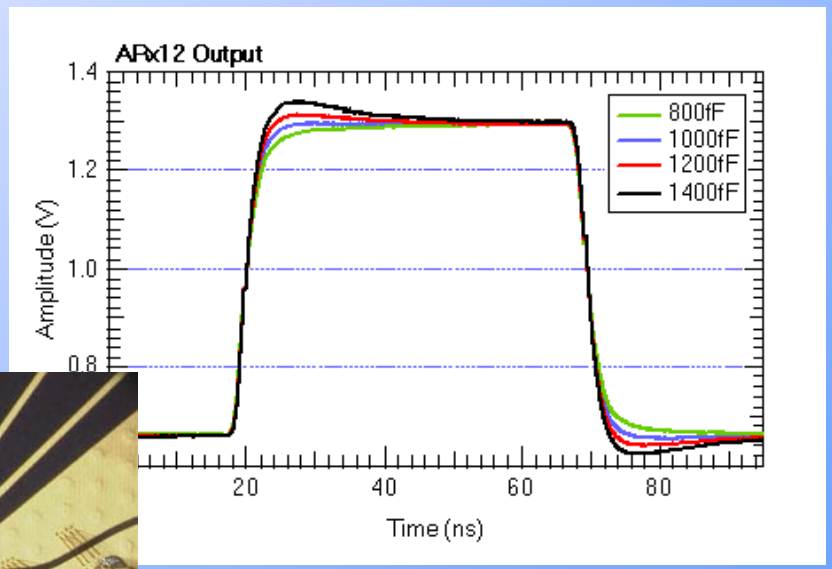


- Confined space
  - Small Form Factor

Technical Specificity

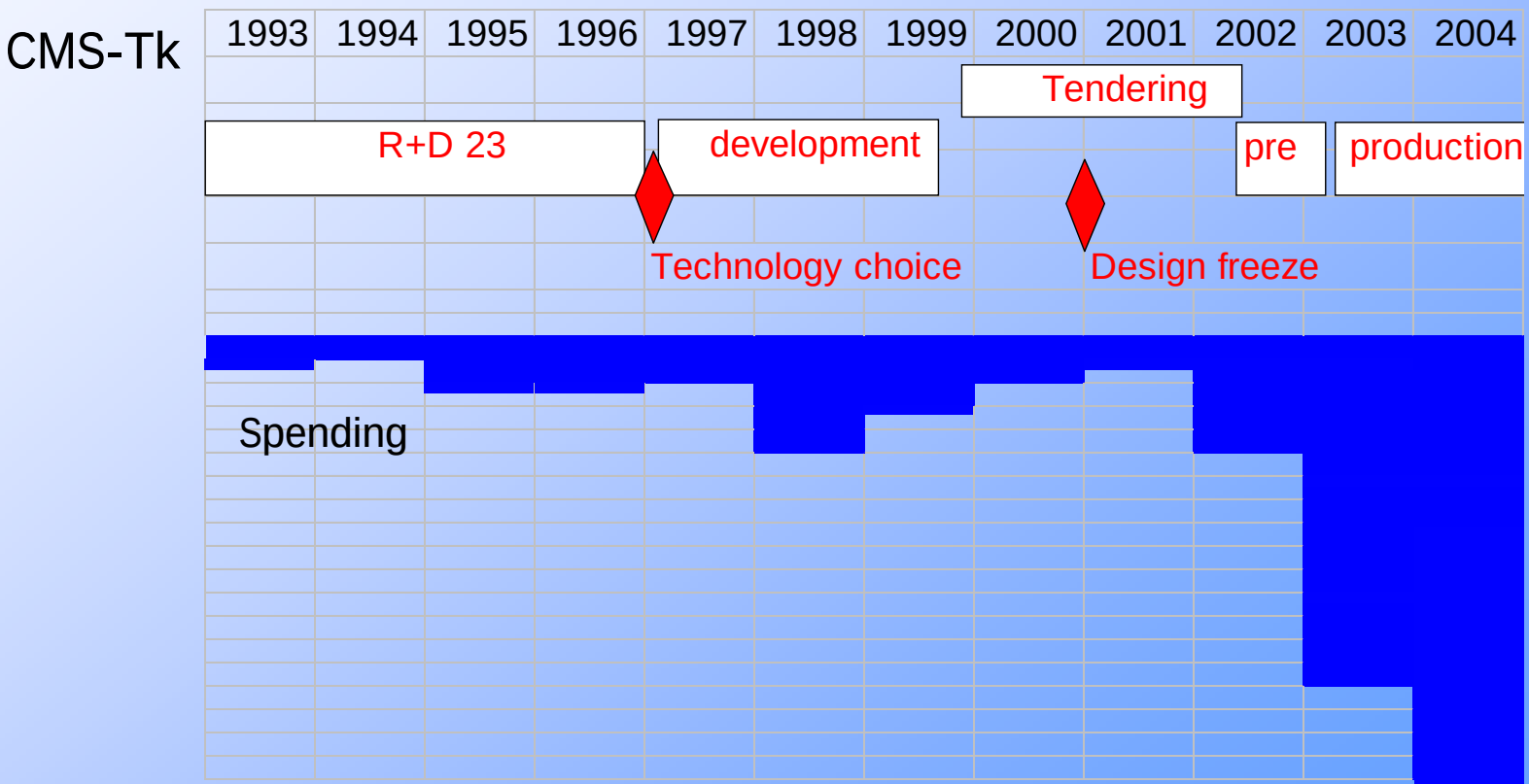
- Application driven specifications
  - Non-standard protocoles
    - 40k PMA analogue links
      - 12 channel analogue Rx module with tunable time response





Organizational Specificity

- Collaboration
- Not for profit
  - Distributed decision centers
  - Flexible timescales



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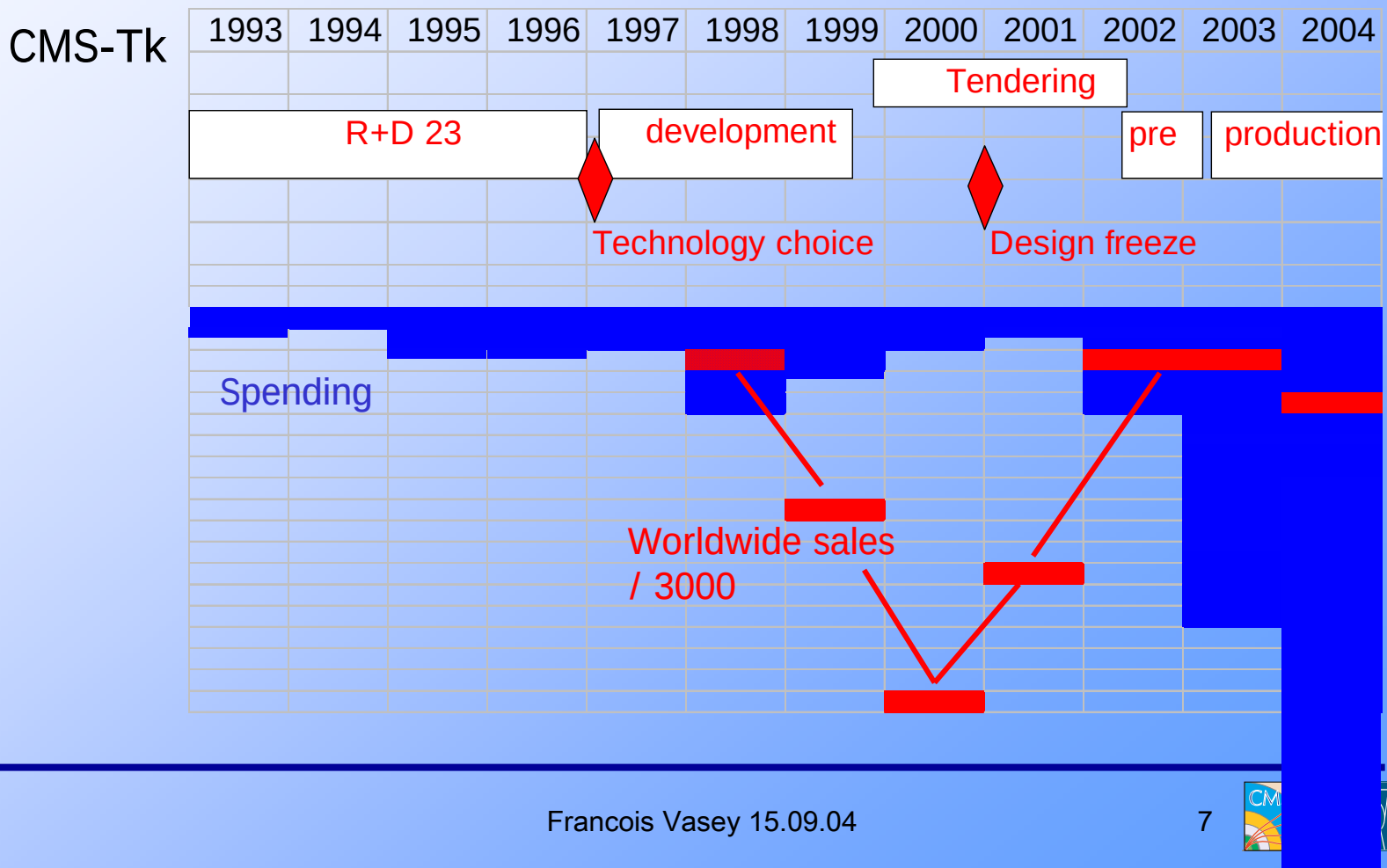
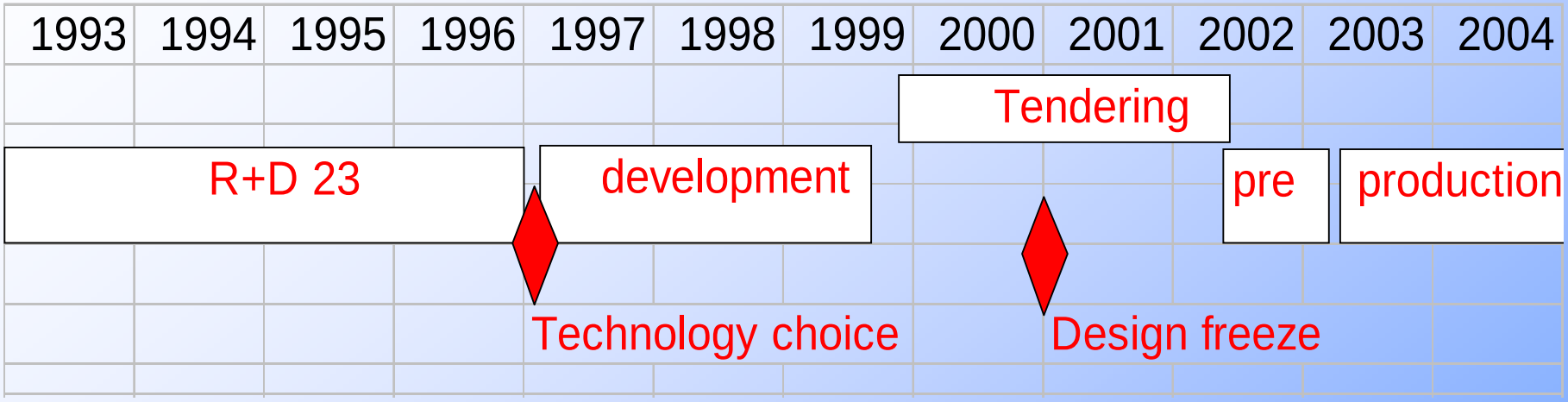


Optical Links for LHC: Conclusions

- We are different
  - Unique application
    - Non telecom/datacom
    - Significant volumes
    - Single shot
  - Unique requirements
    - Environmental
- But quite similar
  - Technology is going in the right direction
    - Components are intrinsically rad-tolerant
    - Small Form Factor
    - Capabilities exceed our needs
  - Society is becoming global
    - Companies operate worldwide
    - Global networks function

- Customize
- Qualify
- COTS
- Learn

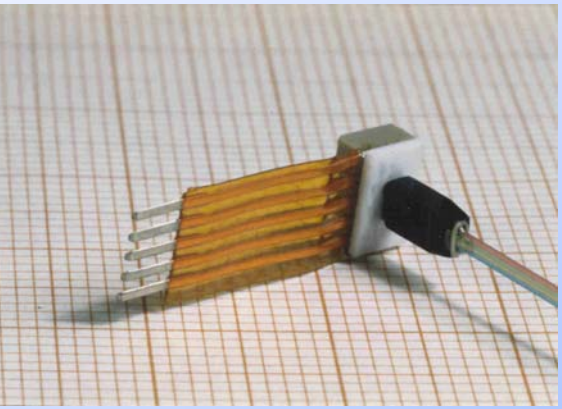
Lessons learned

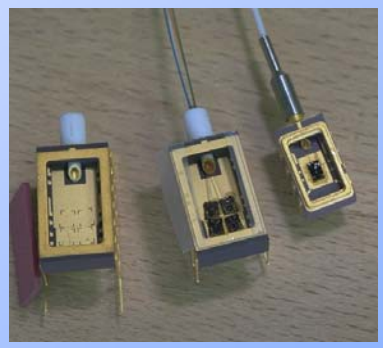


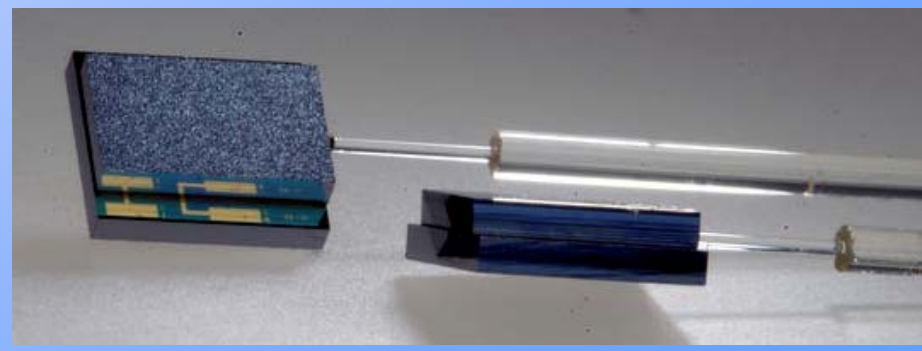
Custom development,
single source

COTS multi-source

+ qualification







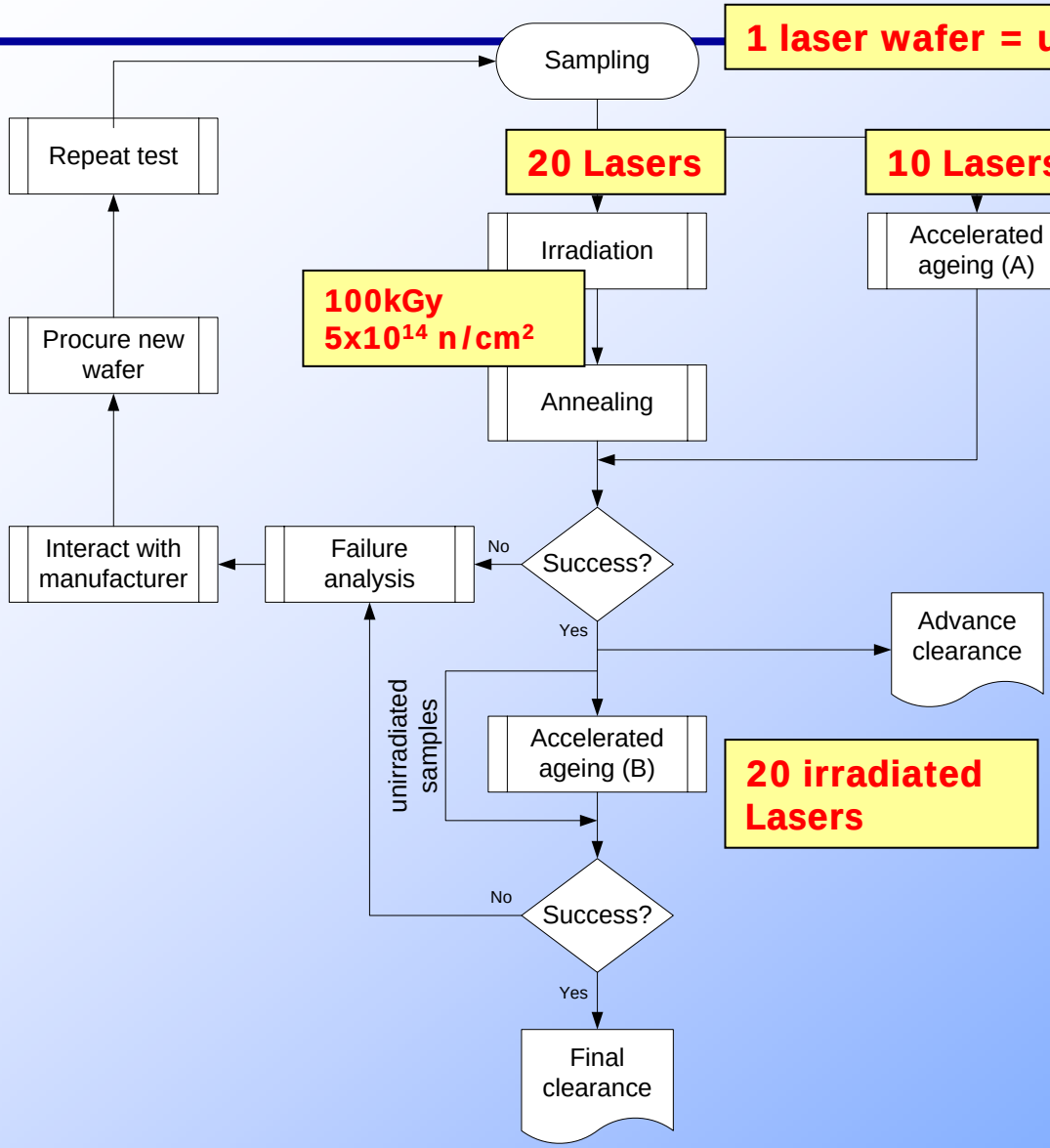
Lesson learned 1: development

- Do not delegate developments
- Understand technology
- Keep control of technology choices

Lesson learned 2: COTS

- COTS are the way forward
  - Rad tolerance is not specified to the supplier
- Robust qualification plan must be put in place
  - Validate rad-tolerance of pre-forms and wafers
- Some customization may be required
  - Connector spring and guide pins
  - Un-rugged assemblies
  - Dedicated electronics

Wafer Validation Test Procedure



LD AVT 0 finished 12/02
3k lasers

LD AVT 1 Finished 2/03
+11.4k lasers

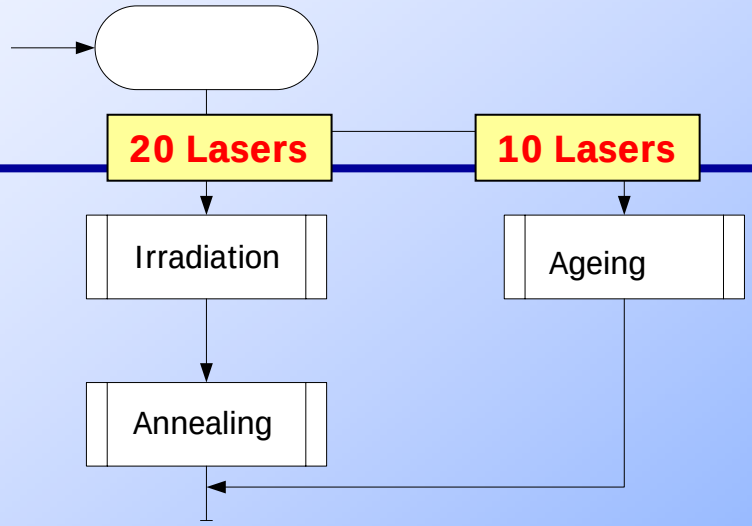
LD AVT 2 finished 9/03
+20.4k lasers

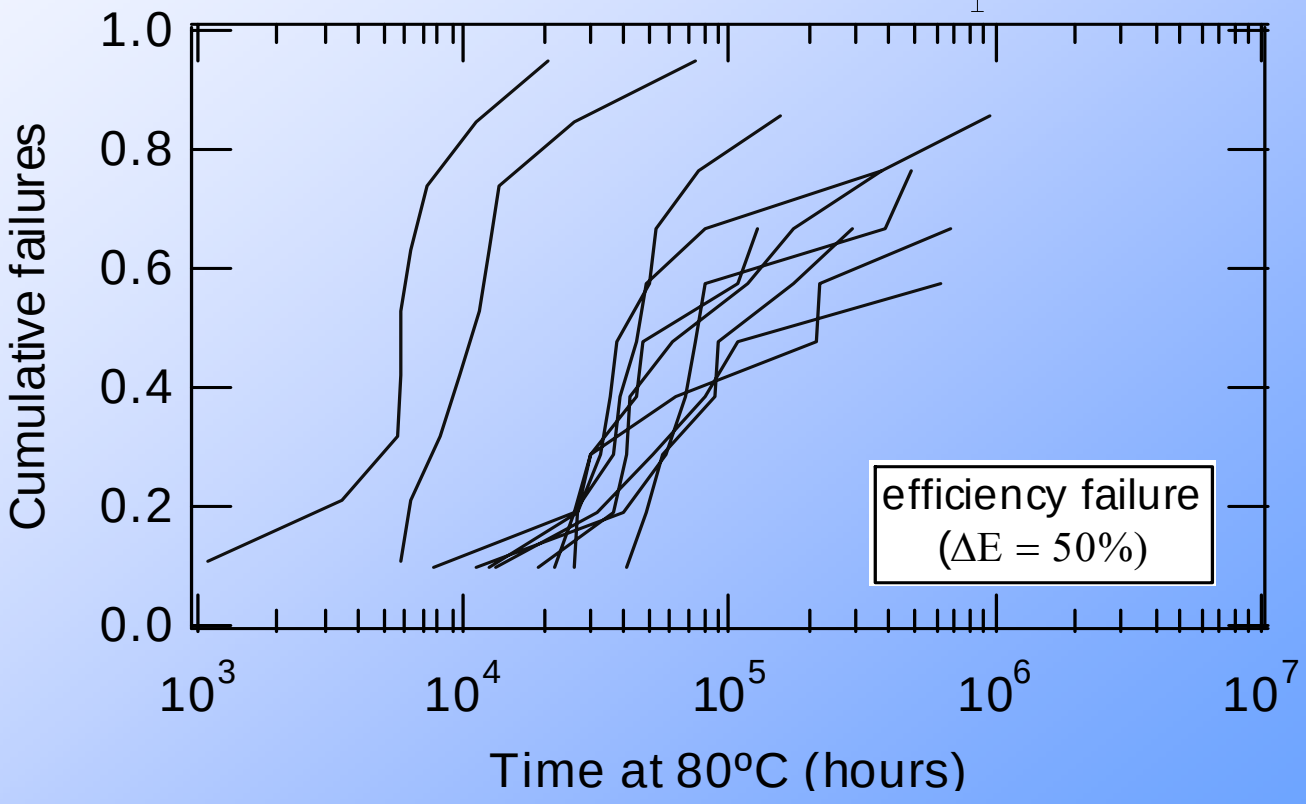
LD AVT 3 finished 5/04
+20k lasers

LD AVT 4 finished 8/04
+22.3k lasers

Total 67.1k lasers OK (11w)
10.0k lasers NOK (2w)

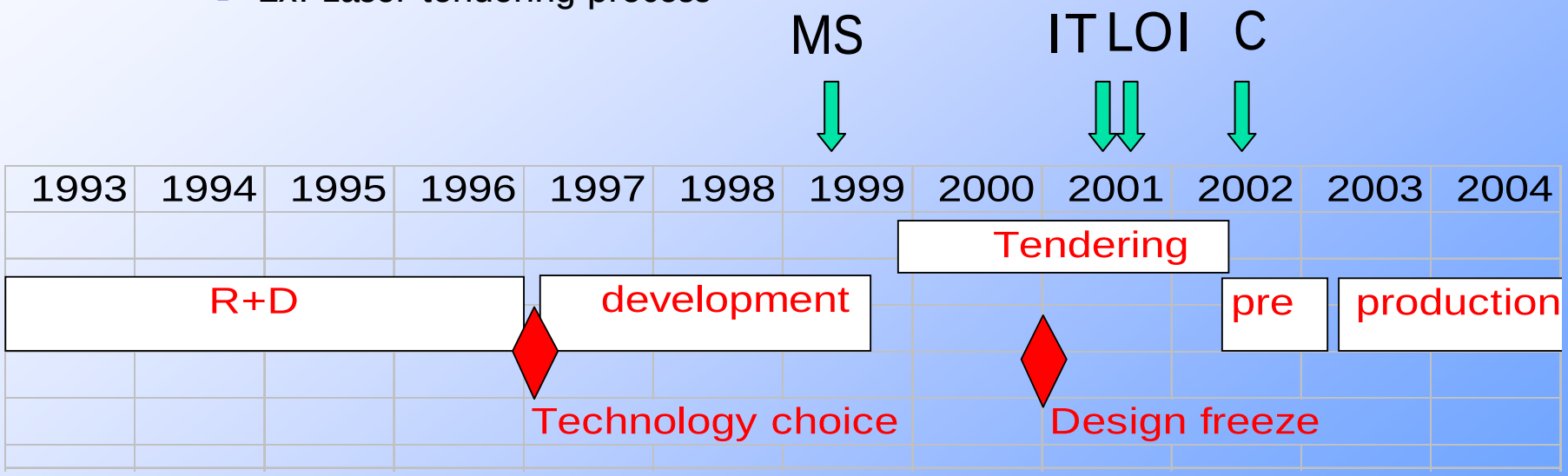
Wafer Reliability





Lesson learned 3: Commercial aspects

- Commercial readiness is as important as technical readiness
- Supplier selection is challenging
  - 2-3 years from market survey to contract
    - Ex: Laser tendering process

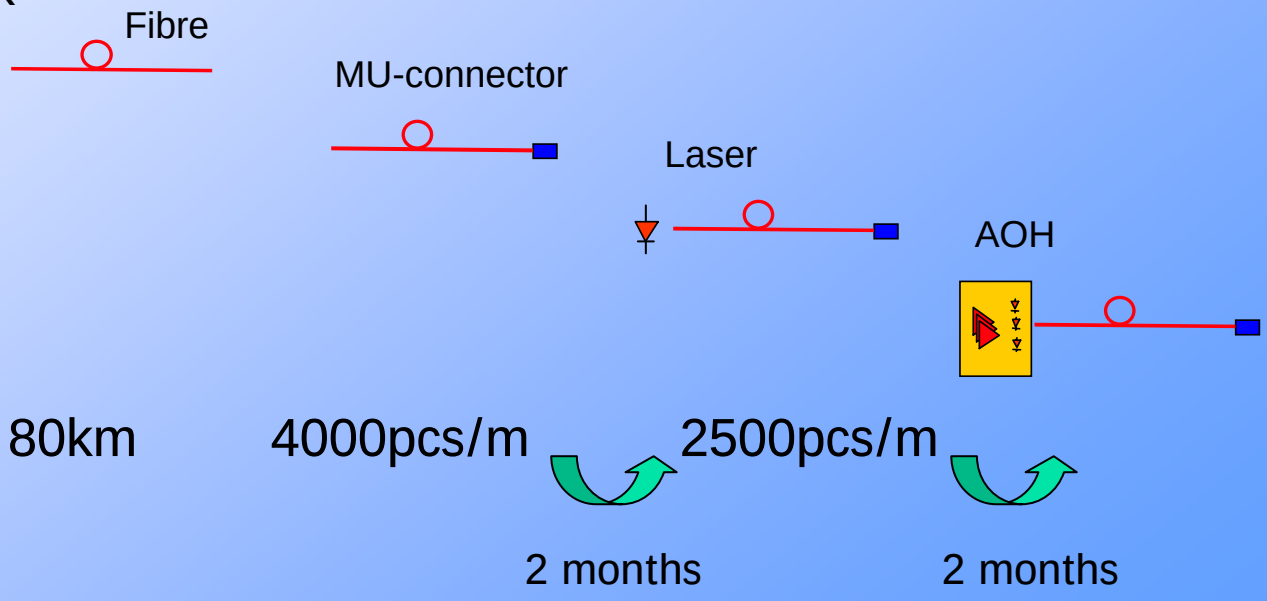


  - Should be integrated into development phase of project

Lesson learned 4: Production

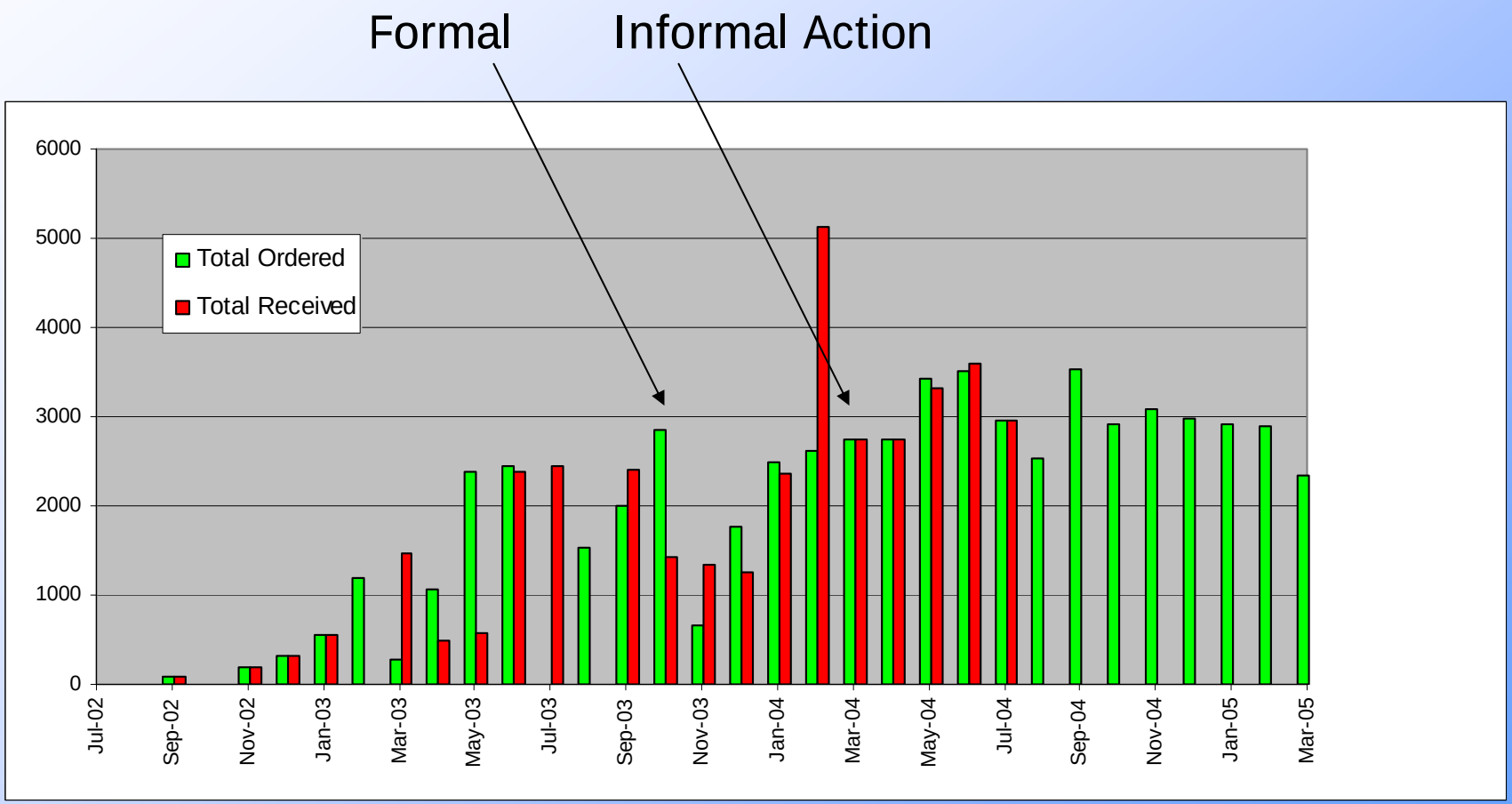
- Suppliers also learn when producing customized products
  - 8 failed qualifications (out of 12)
    - 5 months delay on average (min 3 max 9)

- Non conformities do occur during production
  - Install robust QA plan
  - Allow time to ramp-up
  - Ensure fast feedback
  - Shorten pipelines



Lesson learned 5: Industry

- Good and tight relationship to industry is key to success



Lesson learned 5

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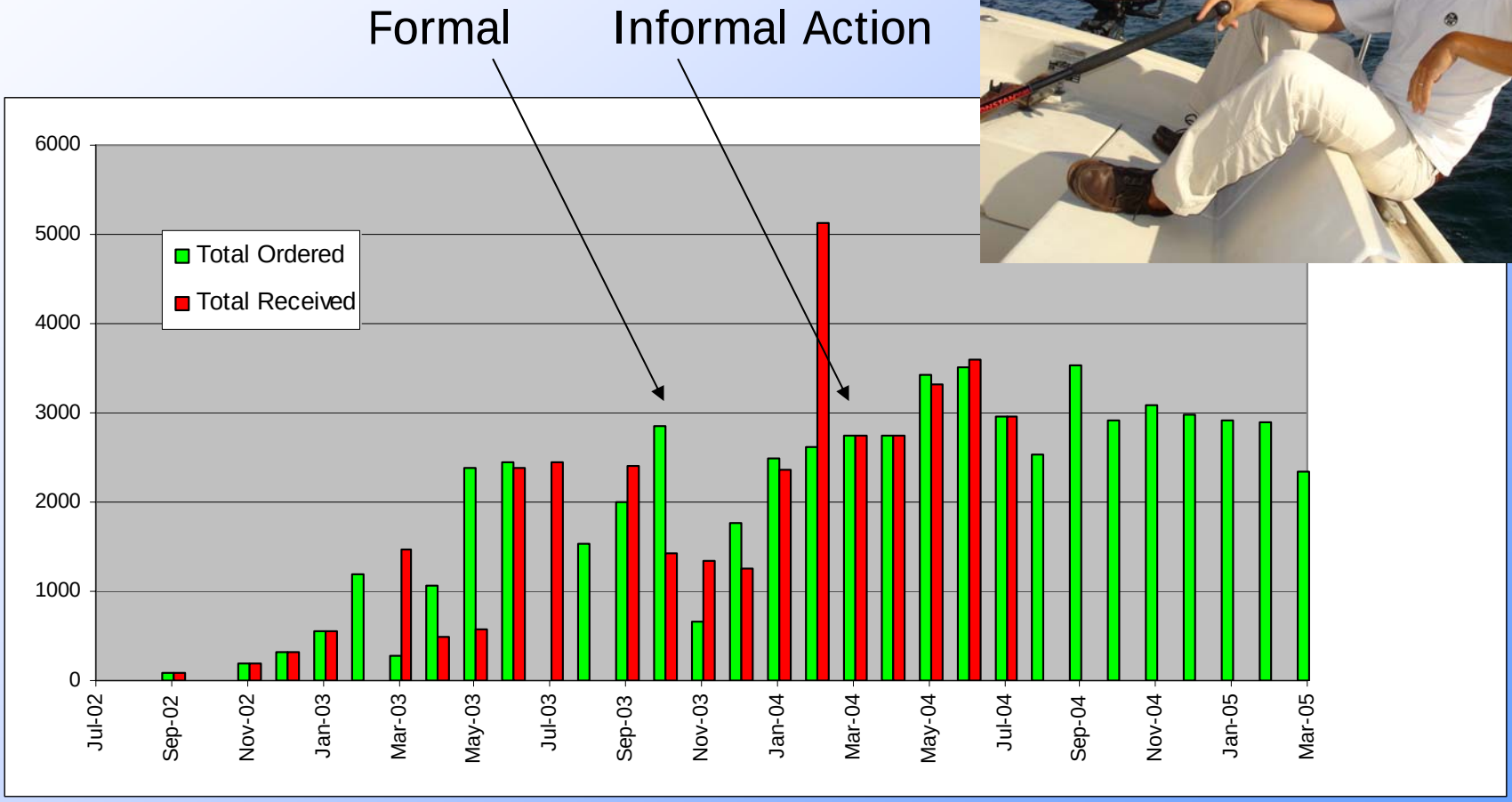
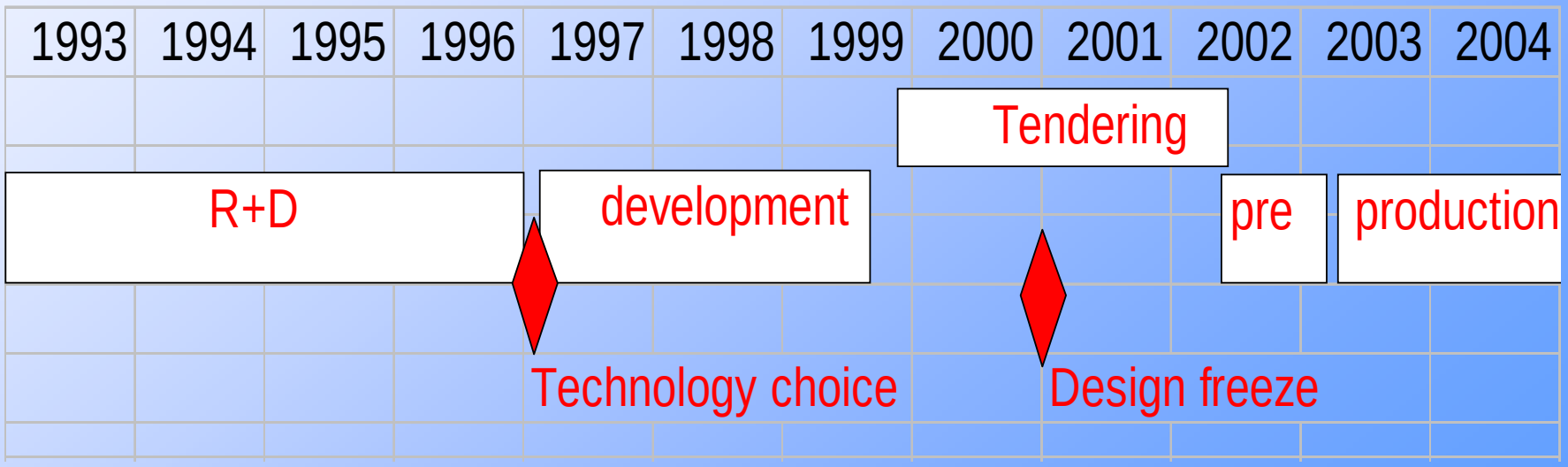


Lesson learned 6: common effort

- Economies of scale are possible
  - Common developments
    - ATLAS-CMS multi-ribbon cable
  - Common qualifications
    - CMS-Alice SM fibre
  - Common spares
    - CMS Tk-ECAL
- Cost structure which excludes manpower overshadows medium/long term benefits

Lessons learned : summary

1. Do not delegate development, understand technology
2. Use COTS with minor customization
3. Commercial readiness is as important as technical readiness
4. Be prepared for non-conformities
5. Have good and tight relationships to industry
6. Economies of scale are possible



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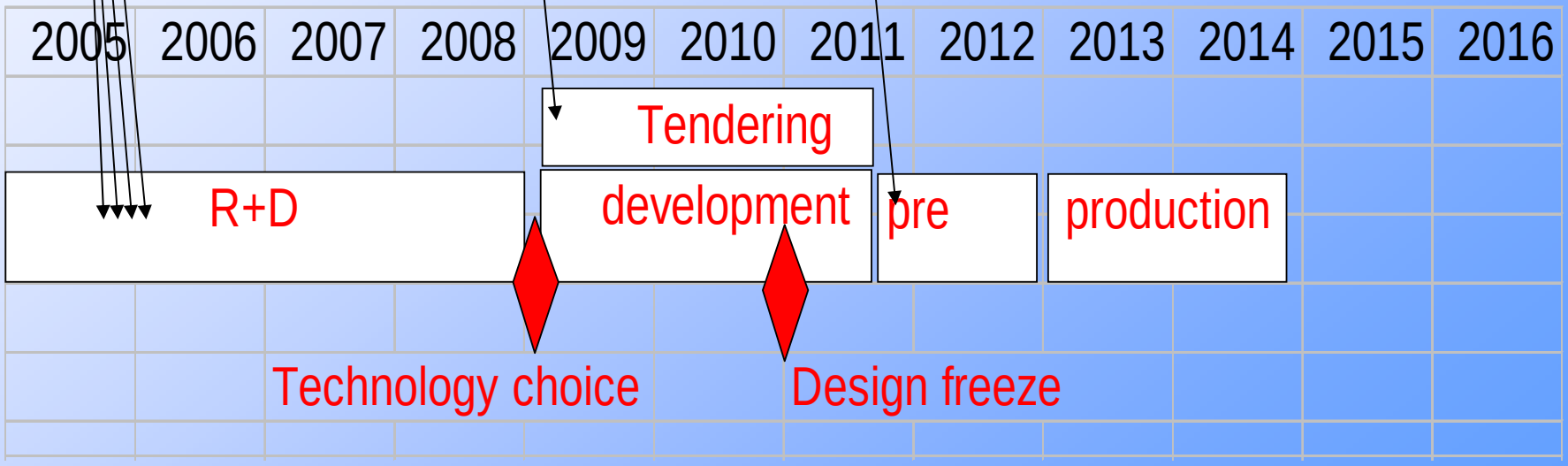
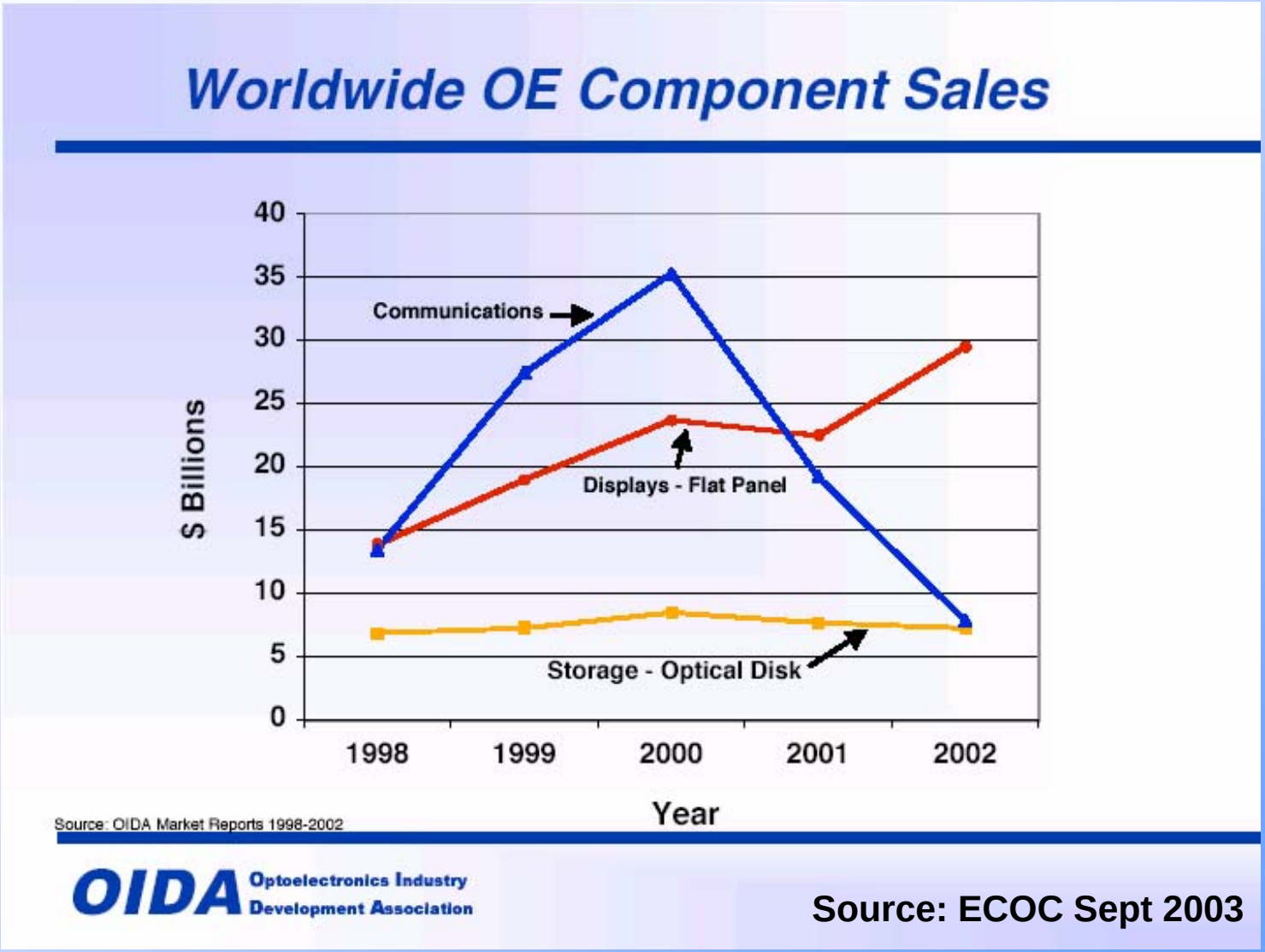
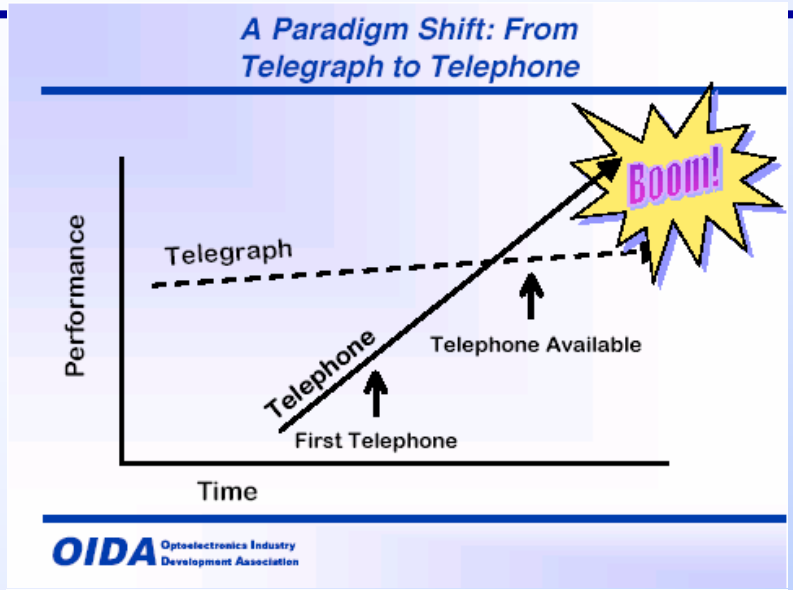


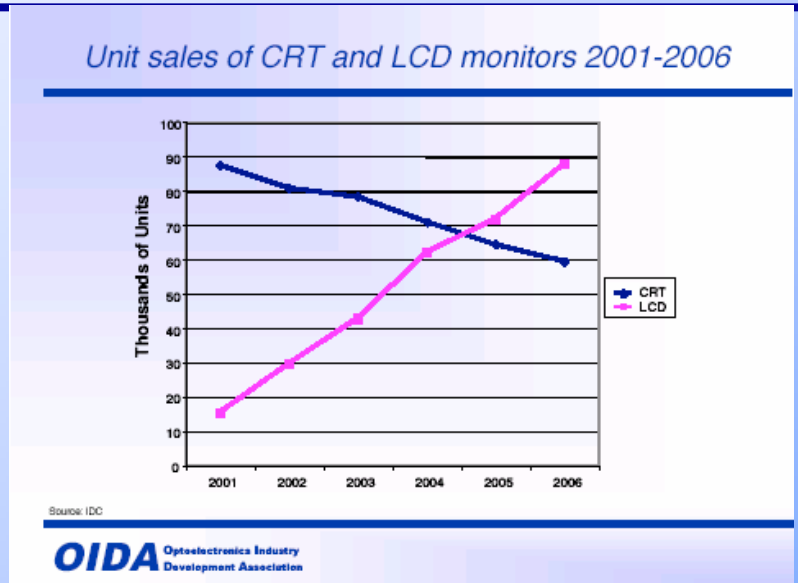
Future trends: Optoelectronics is not only telecommunication

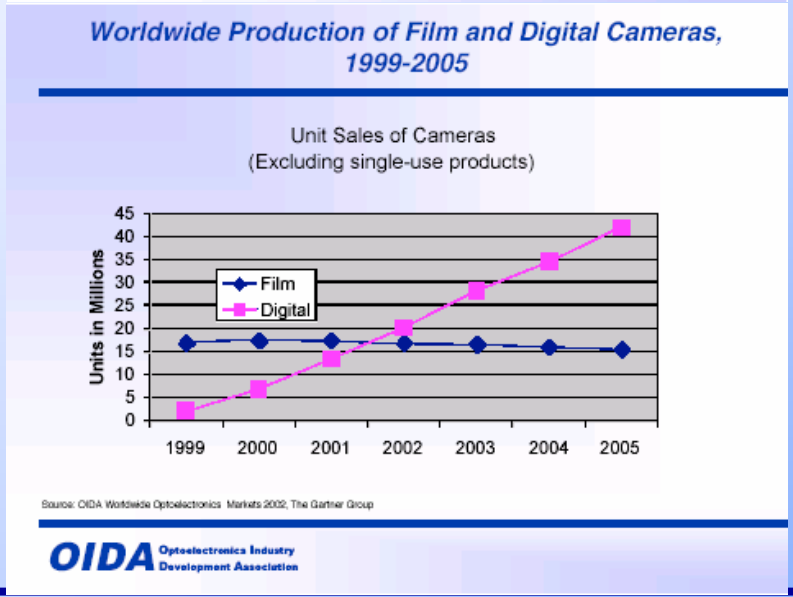


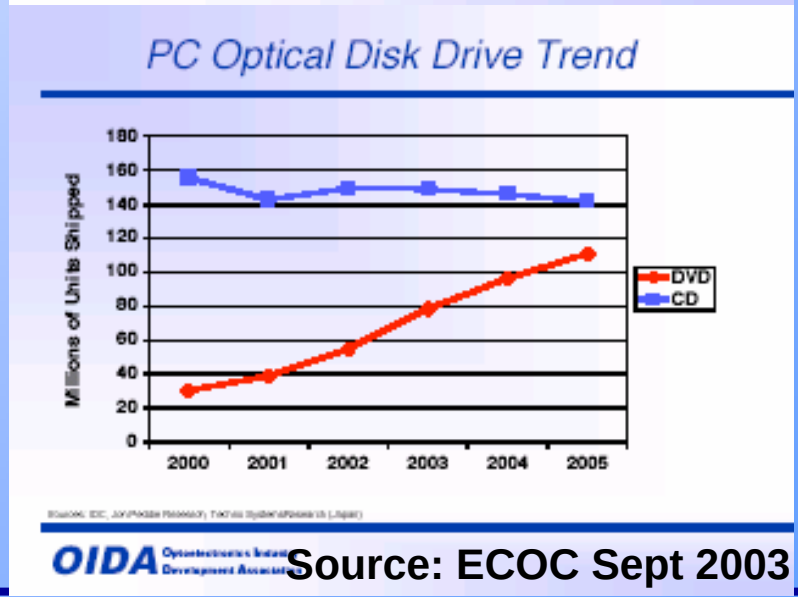
Source: ECOC Sept 2003

Future trends: Paradigm shifts









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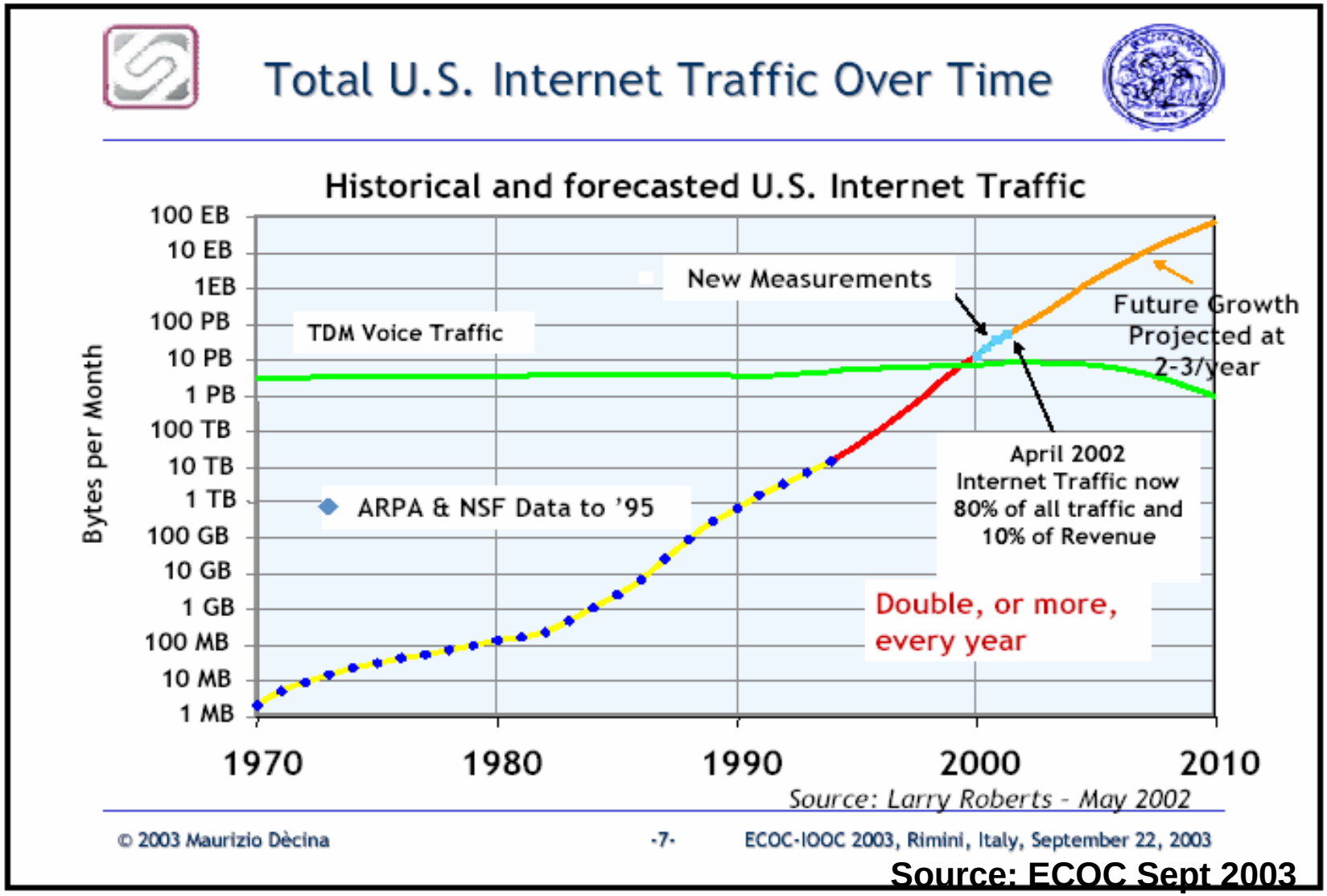
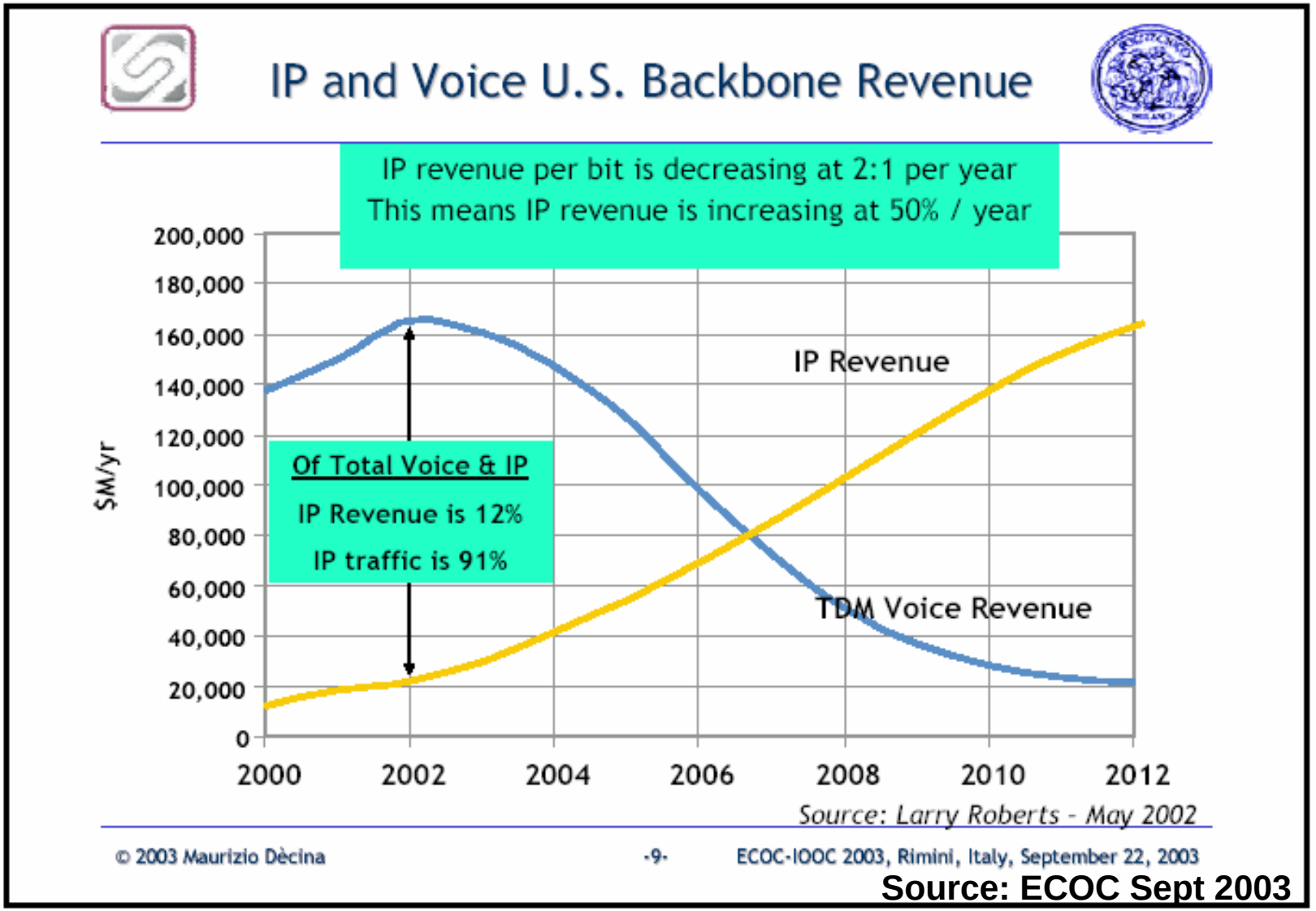
Future trends: Data outweighs Voice traffic



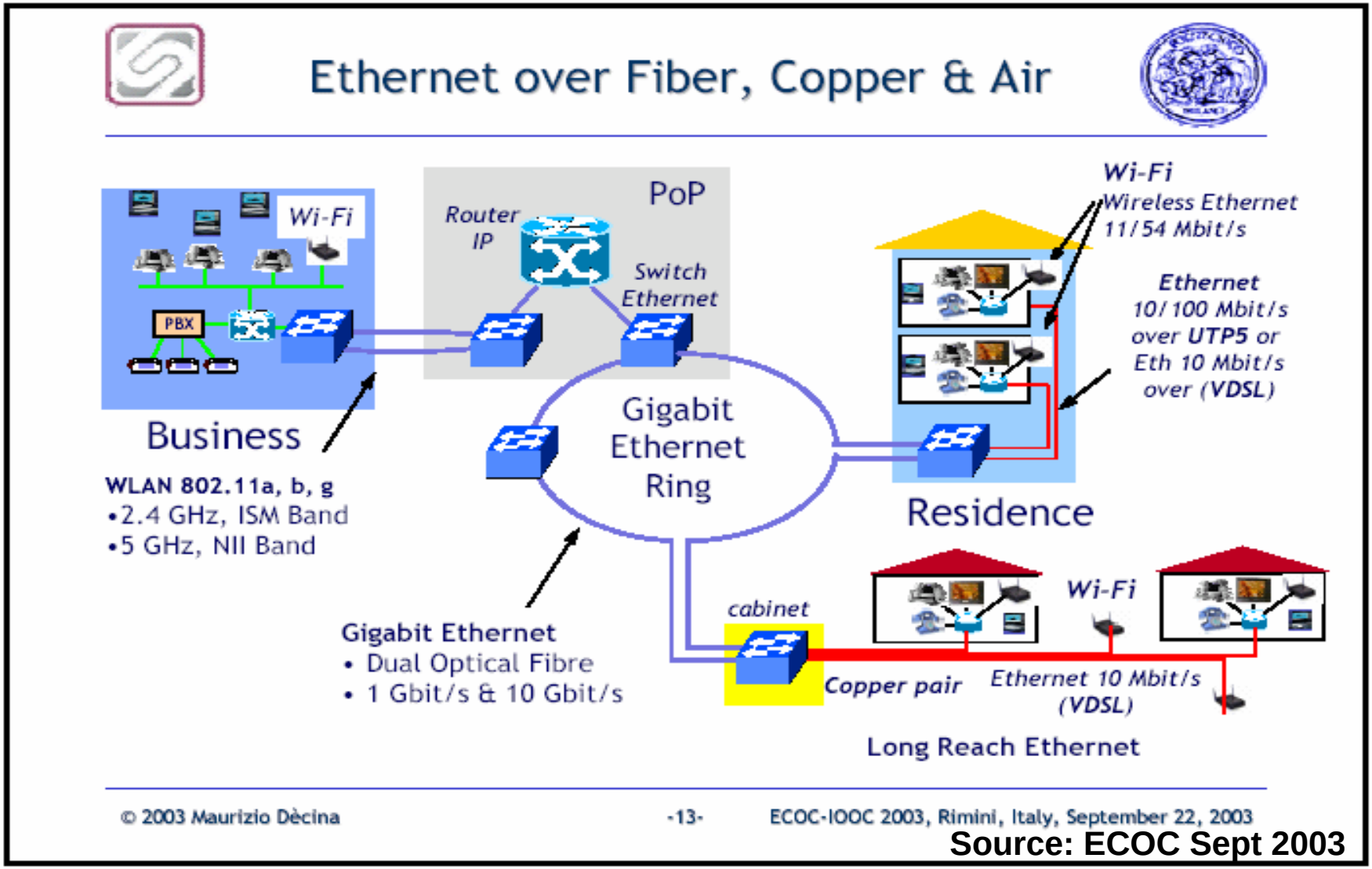
Source: ECOC Sept 2003

Future trends: The economic model



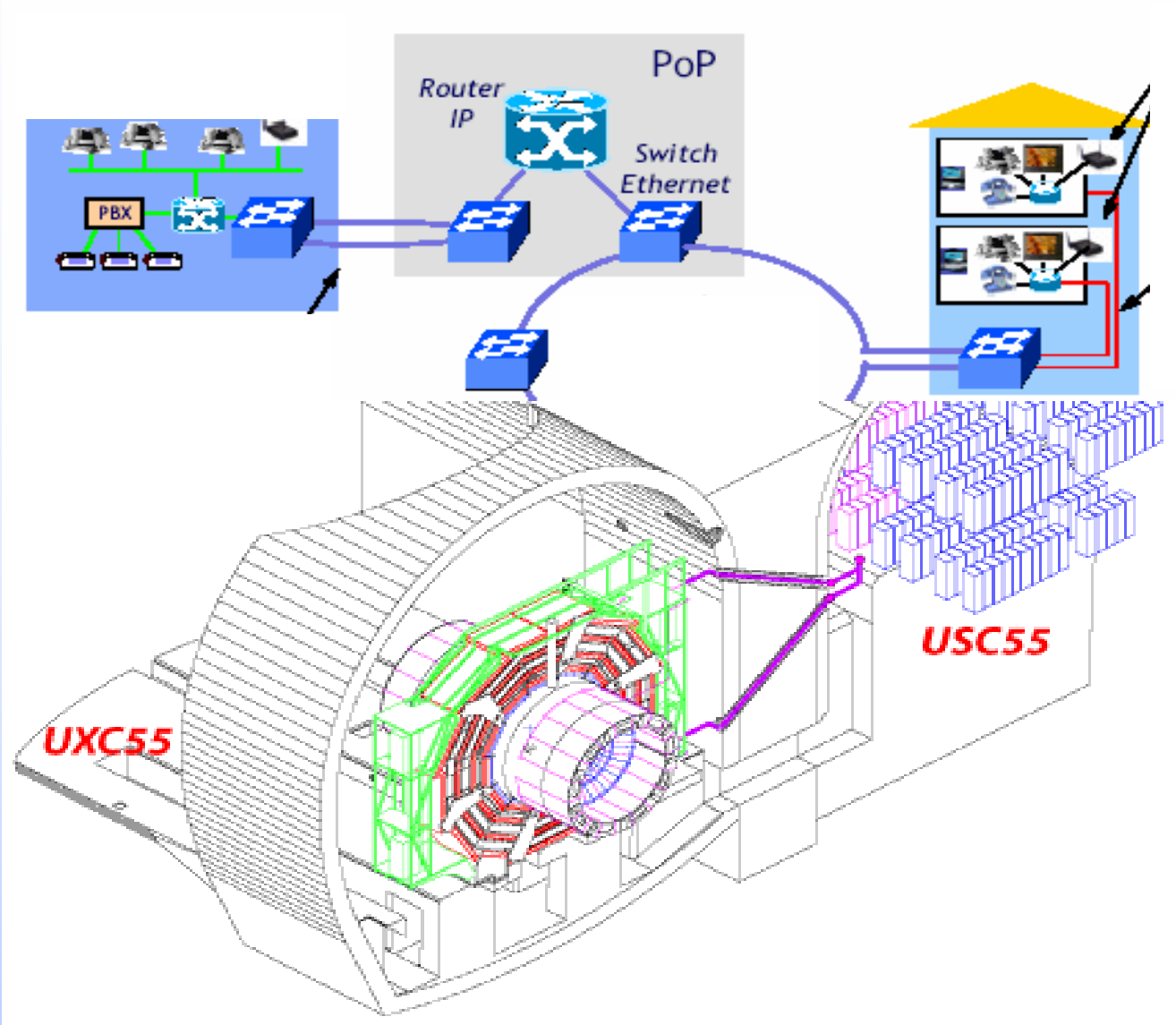
Source: ECOC Sept 2003

Future trends: Model for a data-centric access network



Source: ECOC Sept 2003

Future trends: Model for a data-centric Detector



Future trends: Conclusion

- Data revolution is taking place
- Optical Technology (TDM&WDM) is ready
  - Business models and regulatory issues still unclear
  - Market will continue consolidating for a while
  - Other technologies are competitive
- Intelligence migrates to the edge of access network (increase service-based revenues)
  - Access network becomes LAN
  - Opto modules are becoming intelligent
  - ASICs are the enablers (40Gb/s, Equalization/Compensatio, FEC, Control/Diagnostic)
- Migration from 10Gb/s to 40Gb/s is underway but is a significant technical challenge.

While technology evolves, we can:

- Get acquainted with 10Gb/s technology
- Learn from existing networks

R+D model

1. Technology Watch
   1. Components
   2. Packages
   3. Total dose/fluence and SEE

2. 10Gb/s Link Demonstrator
   1. Components
   2. Equipment
   3. Layout techniques
   4. Diagnostic techniques
   5. EMC

3. System Design
   1. Protocols
   2. Coding & compression techniques
   3. Error correction techniques

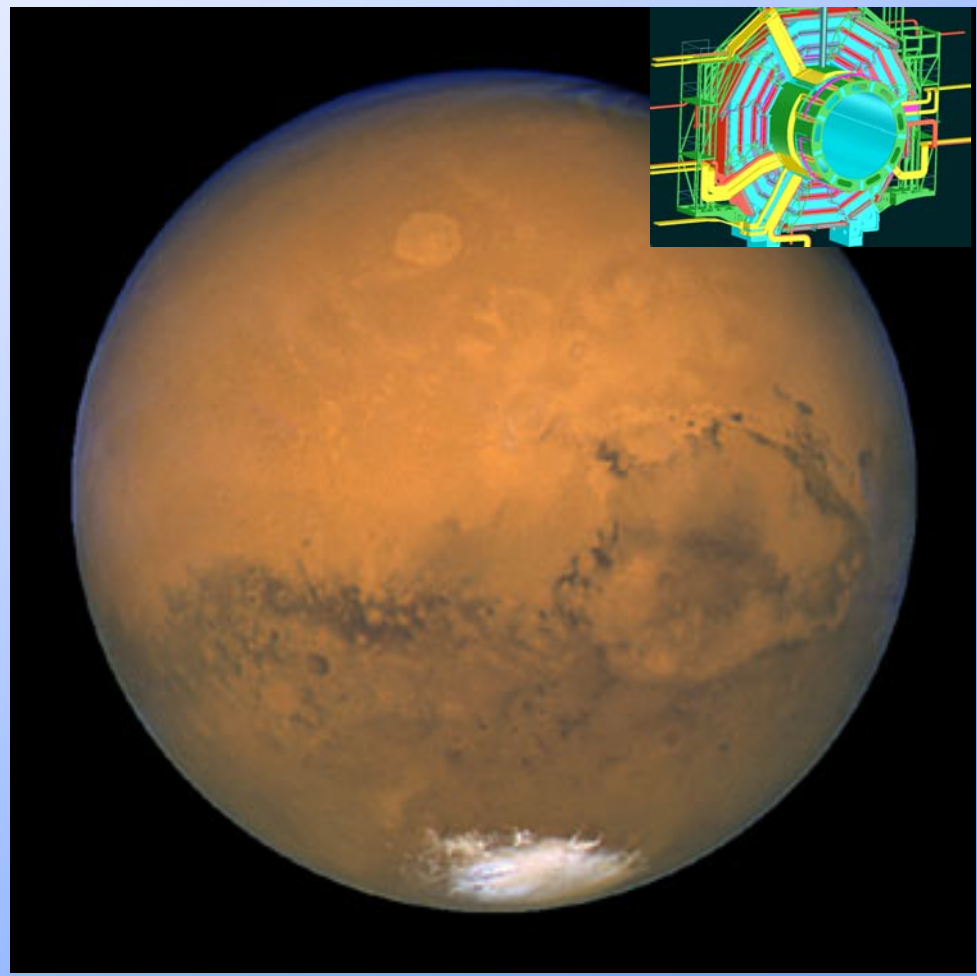
- KNOWLEDGE
- Rolling Market Survey

- EXPERTISE
- Hands-on experience
- Industrial contacts

- INTELLIGENCE

Conclusion

- Optical links for LHC
  - A big city on Mars
- Lessons learned
  - Martians have a lateral vision deficit
- Future trends
  - Abolish trade barriers between Earth and Mars



Conclusion

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- Quiz:
  - Will we see a paradigm shift in design of electronics for S-Detectors?