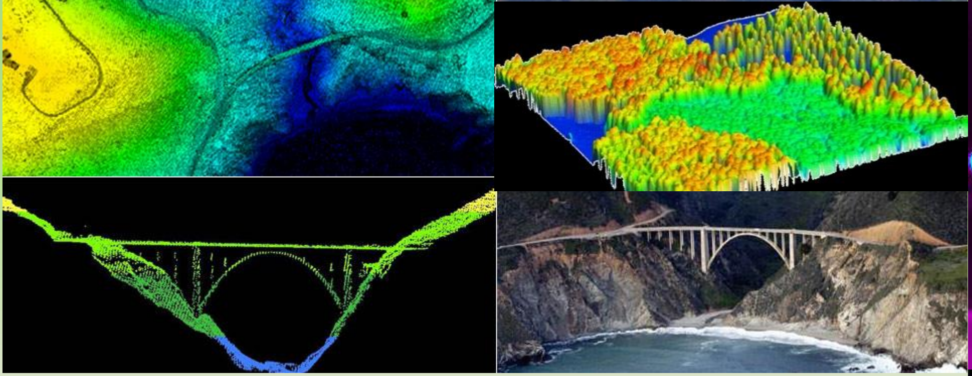
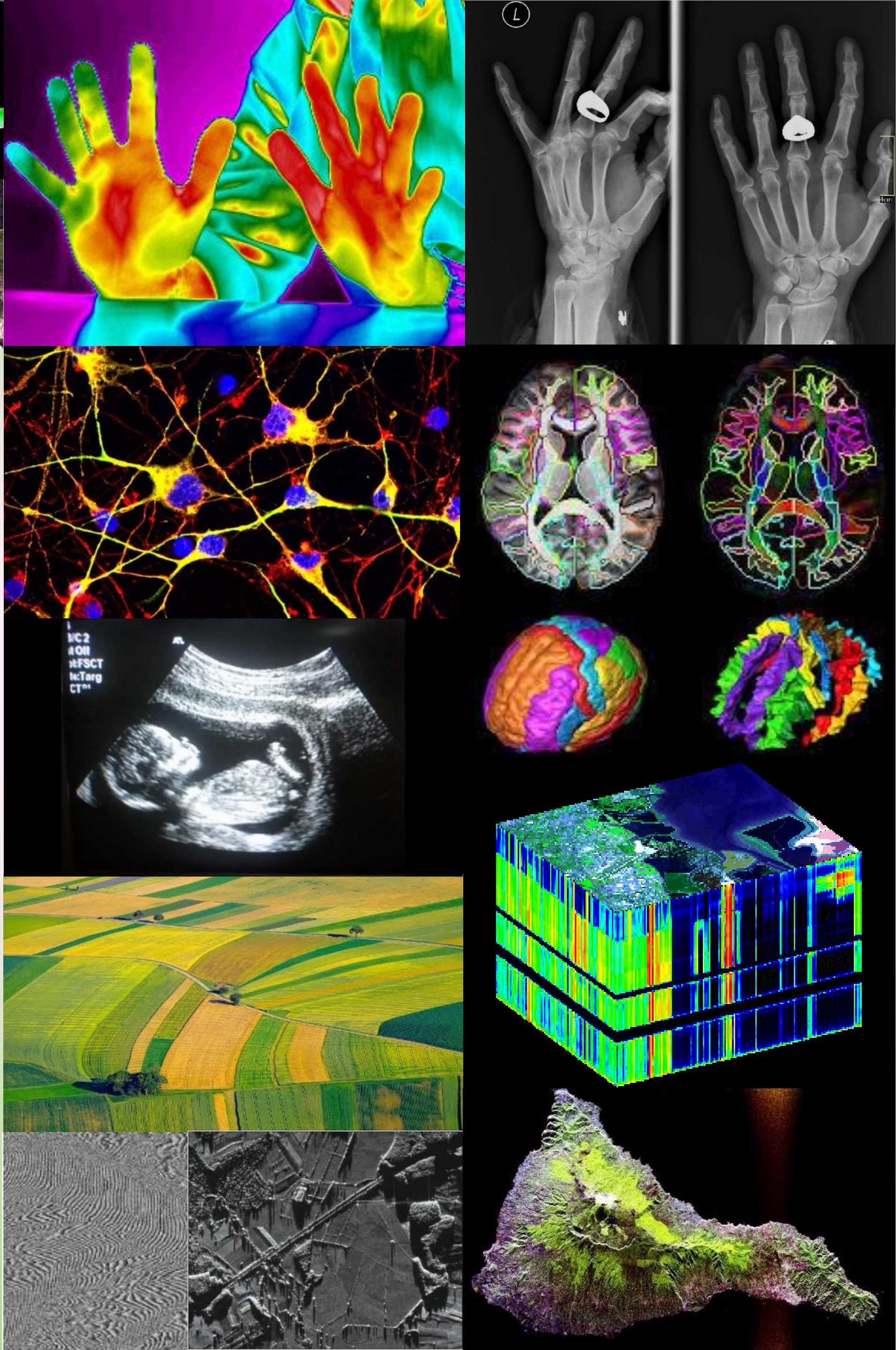




Ciências ULisboa

Applied Optics & Lasers

Engineering Physics

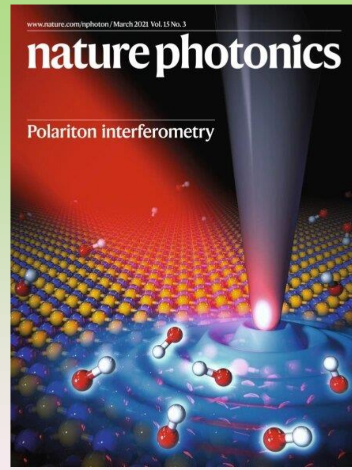
José Manuel Rebordão
João P. Coelho

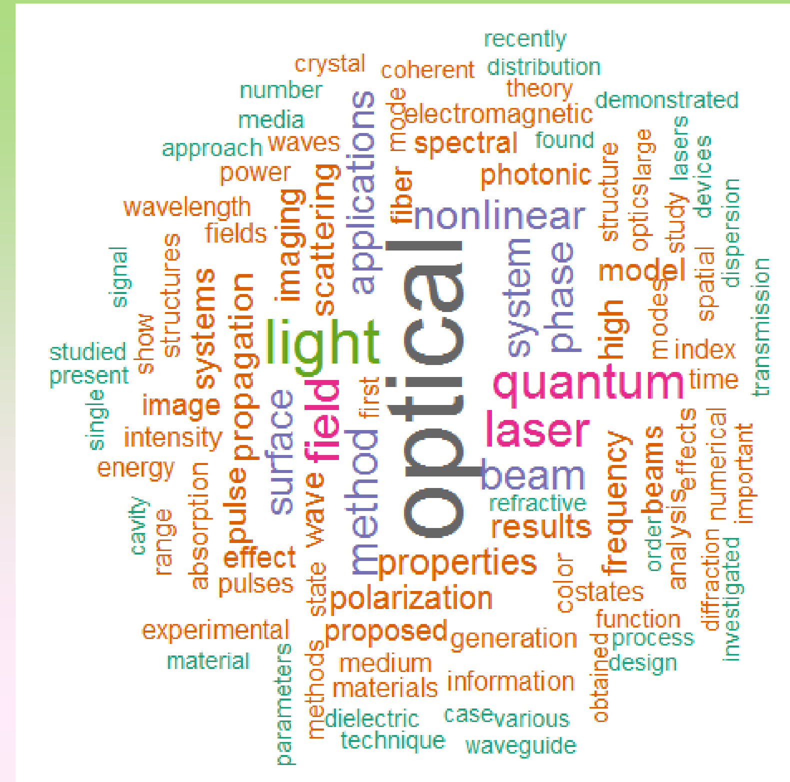
2021/2022

1ª aula

- A disciplina: estudantes, objectivos, conteúdo, bibliografia, avaliação
- Funcionamento em 2021/21: T e PL's
- A indústria fotónica
- Maturidade tecnológica: *Technical Readiness Levels* (TRL) e conceitos afins


applied optics
OSA 100


nature photonics
Polariton interferometry


optical
light
quantum
laser
beam
nonlinear
properties
polarization
method
field
surface
propagation
systems
scattering
imaging
applications
system
phase
high
model
frequency
beams
results
effect
pulses
pulse
proposed
generation
experimental
material
medium
materials
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dielectric
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waveguide
parameters
methods
state
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range
cavity
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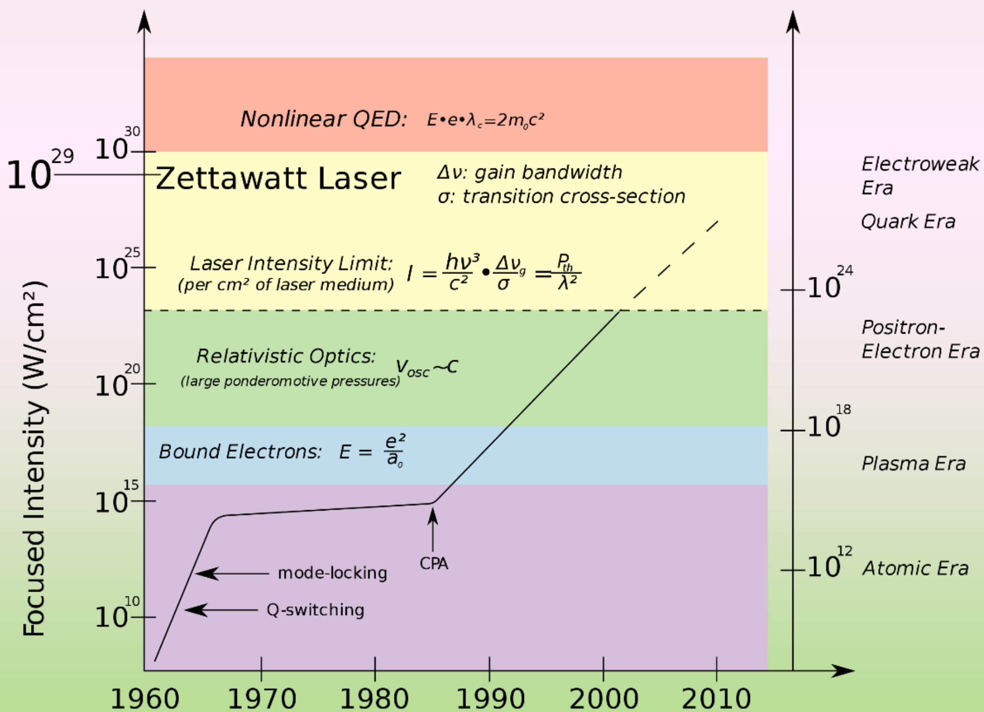
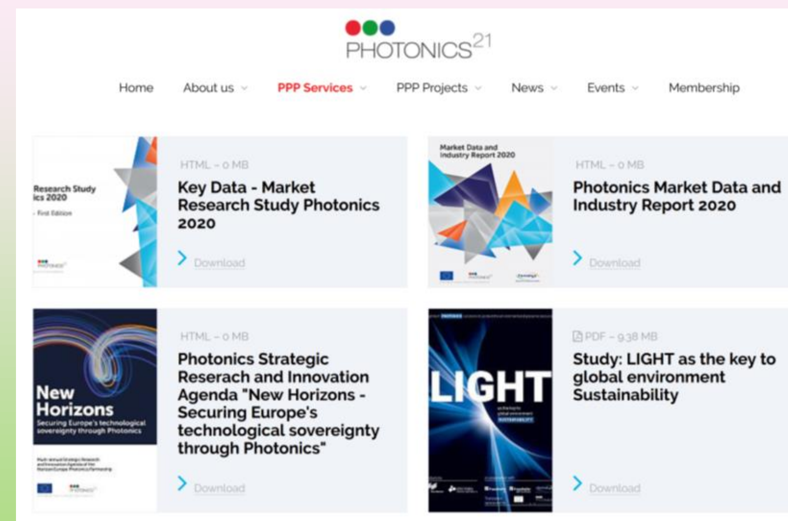
important


Focused Intensity (W/cm²)
Nonlinear QED: E•e•λc=2mec²
Zettawatt Laser
Δν: gain bandwidth
σ: transition cross-section
Laser Intensity Limit:
(per cm² of laser medium)
I = hν³/c² • Δνg/σ = Pth/λ²
Relativistic Optics:
(large ponderomotive pressures)
vosc~c
Bound Electrons: E = e²/a0
mode-locking
Q-switching
CPA
10^29
10^30
10^25
10^20
10^15
10^10
10^24
10^18
10^12
1960
1970
1980
1990
2000
2010
Electroweak Era
Quark Era
Positron-Electron Era
Plasma Era
Atomic Era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Photonics Strategic Reserach and Innovation Agenda "New Horizons - Securing Europe's technological sovereignty through Photonics"
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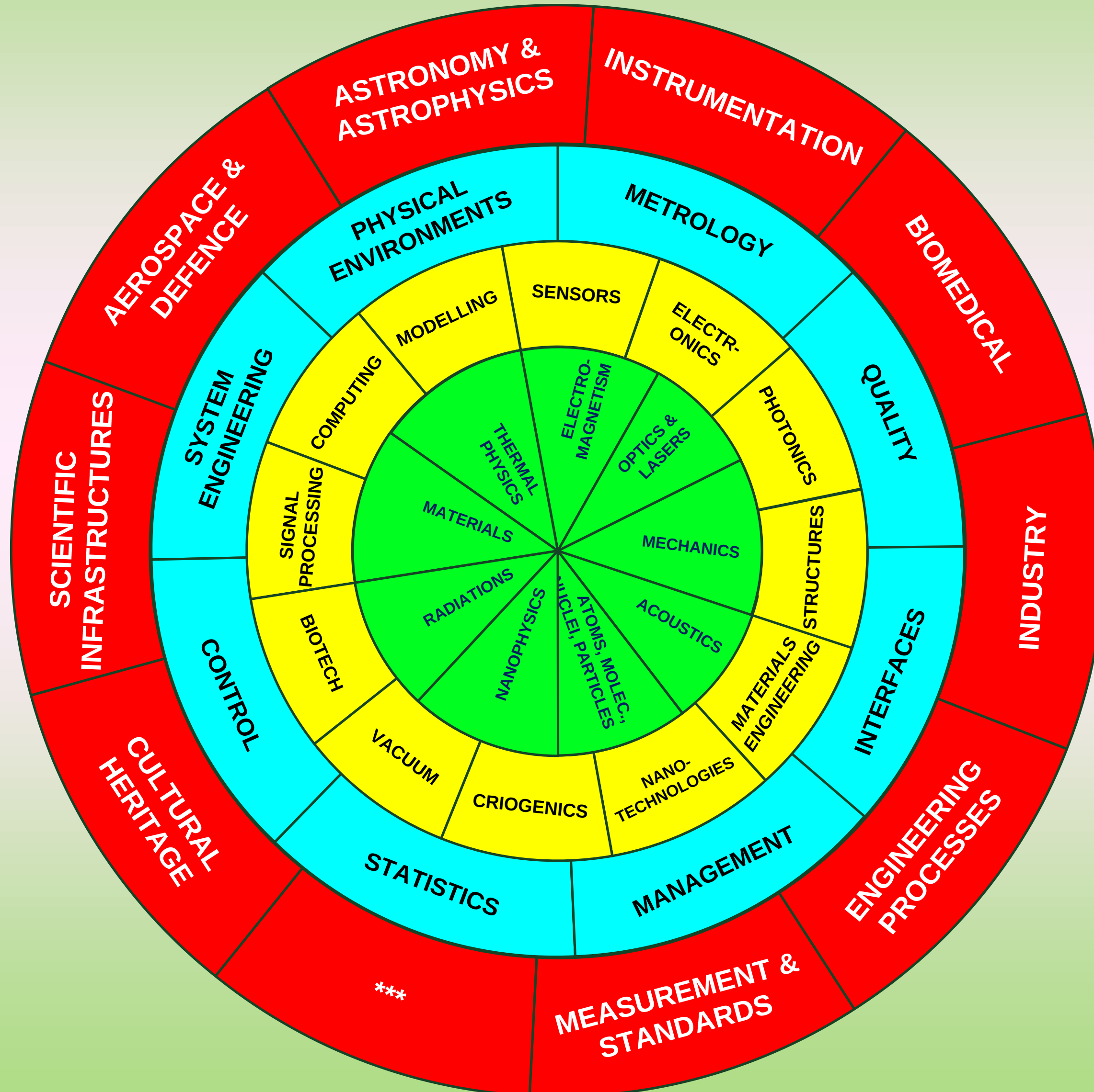
New Horizons
PDF - 9.38 MB
Study: LIGHT as the key to global environment Sustainability
Download
LIGHT

Systems @ Edu (MIEF) level

I – PHYSICS FUNDAMENTALS
II – ENABLING TECHNOLOGIES
III – SYSTEM CONCEPTS
IV – APPLICATIONS / MARKETS

PHYSICS
CHEMISTRY
BIOLOGY
IT
MEDICAL
SOCIAL SCIENCES

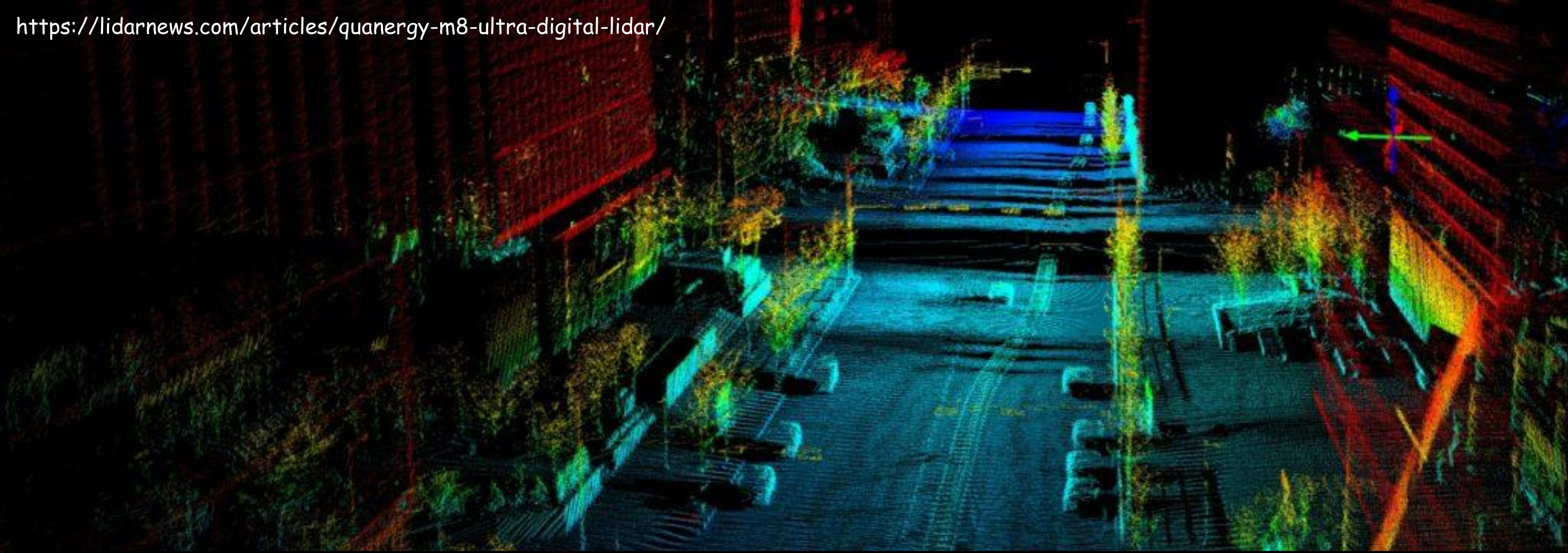
REGULATIONS
PUBLIC POLICIES
PRIVACY
HUMAN RIGHTS
…

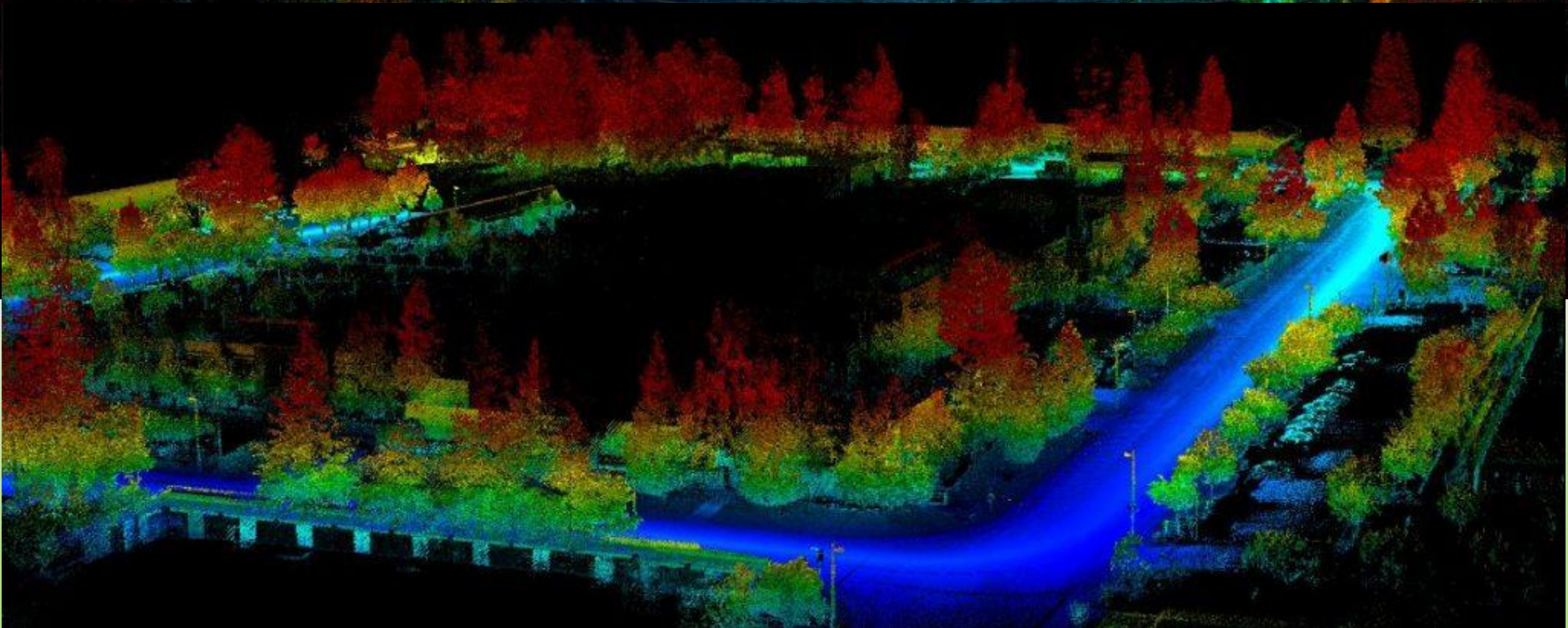


First M87 Event Horizon Telescope Results. II. [I, II, III, IV, V]
Array and Instrumentation
The Astrophysical Journal Letters, 875:L2 (28pp), 2019 April 10
https://doi.org/10.3847/2041-8213/ab0c96

https://www.jpl.nasa.gov/edu/news/2019/4/19/how-scientists-captured-the-first-image-of-a-black-hole/

https://lidarnews.com/articles/quanergy-m8-ultra-digital-lidar/





Students (2021/22)

- Registered – table of students:

General Objectives

A. Conhecer os principais conceitos da óptica e dos lasers (no contexto mais integrado e com vertente industrial da fotónica) relevantes para o desenvolvimento de instrumentação e de aplicações da luz.
B. Apresentar os conceitos e modelos relativos à luz cobrir a compreensão do funcionamento e, ainda, a fornecer ferramentas para a respectiva optimização, passando por aplicações computacionais e simulação.
C. Apresentar diversas opções tecnológicas actuais para a implementação das diversas funcionalidades instrumentais relevantes para as tecnologias e aplicações da luz.
D. Compreender os níveis de interface com os sistemas de detecção, sempre que aplicável.

Contents – **theory**

A - Óptica geométrica

1. Sistemas arbitrários,
2. Aberrações
3. Análise e de desenho de sistemas.

B – Propagação

1. Difracção e Óptica de Fourier
2. PSF, OTF e MTF
3. Tratamento de aberrações
4. Campo próximo, aplicações
5. Modelação numérica.

C – Interferometria e metrologia óptica

1. Duas ondas
2. Ondas múltiplas
3. *Phase shifting e unwrapping* da fase
4. Análise de interferogramas [tempo (desmodulação) e espaço].

D – Polarização

1. Modelação e elipsóide dos índices
2. Óptica dos meios anisótropos
3. Moduladores

E – Radiometria e fotometria

1. Grandezas básicas e principais teoremas
2. Fontes, emissividade, BDRF
3. Irradiância no detector, ruído.

F – Coerência

1. Funções
2. Propagação das funções de coerência
3. Radiometria generalizada

G – Lasers

1. Princípios de funcionamento, ganho, risca
2. Bombeamento
3. Cavidade ressonante, feixes, modos e espectro
4. Geração de impulsos
5. Tipos de lasers e operação
6. Segurança laser

H – Óptica não-linear

1. Efeitos de 2ª e 3ª ordem
2. 2. Sistemas e aplicações

Contents – **laboratory - examples**

Assessment

LABORATORY– 50%

- Relatórios laboratoriais (grupos com não mais de 2 alunos)

PROBLEMS – 20%

- Entrega de 4 problemas resolvidos (metade do número de secções do programa) (20%).

ESSAY– 30%

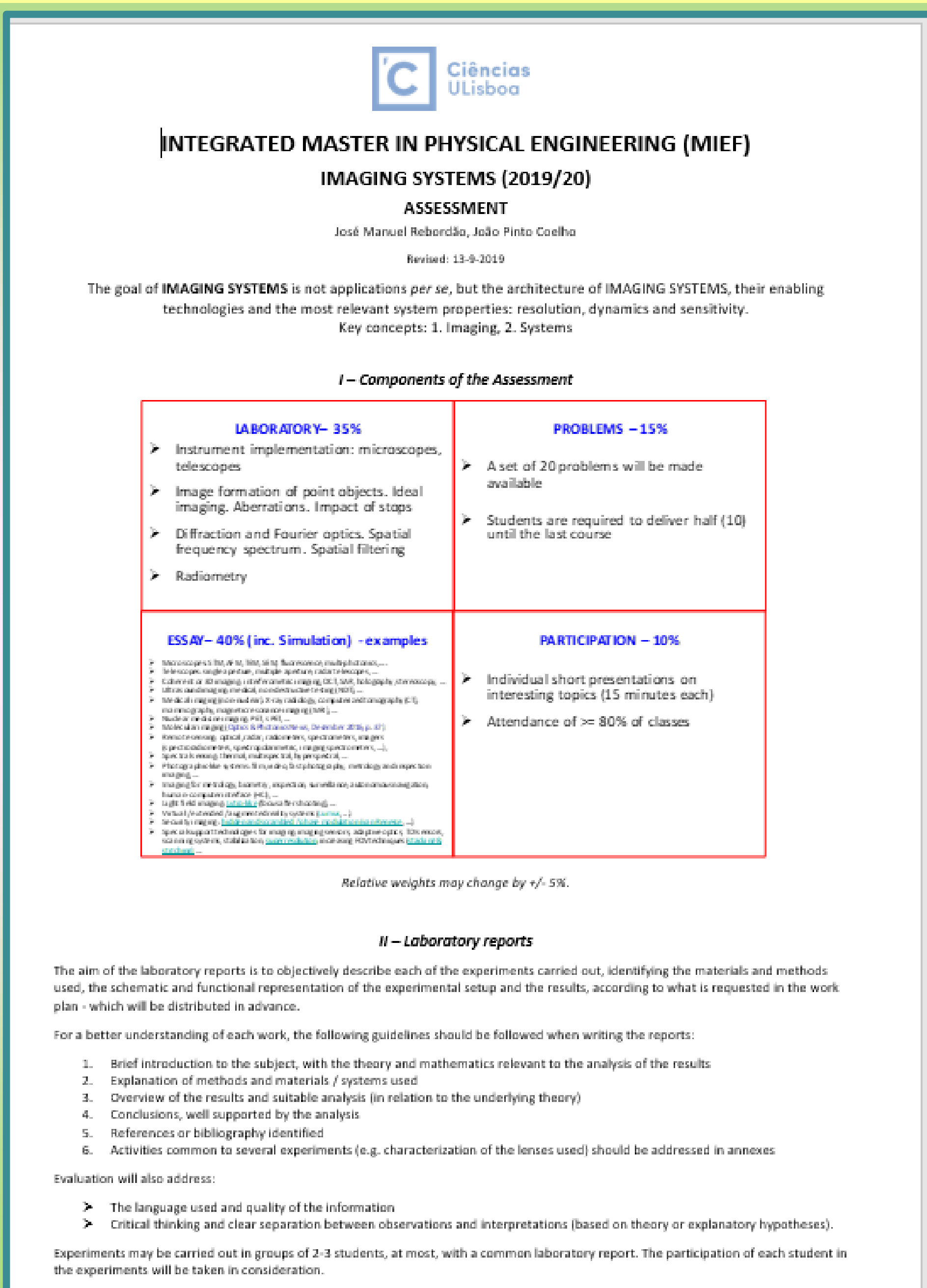
- Monografia individual (10 páginas, formato de artigo a submeter a revista) com apresentação oral

PARTICIPATION – 0%

- ***

Assessment detailed explanation

File available on Fénix & Facebook



Ciências ULisboa

INTEGRATED MASTER IN PHYSICAL ENGINEERING (MIEF)

IMAGING SYSTEMS (2019/20)

ASSESSMENT

José Manuel Rebordão, João Pinto Coelho

Revised: 13-9-2019

The goal of **IMAGING SYSTEMS** is not applications *per se*, but the architecture of IMAGING SYSTEMS, their enabling technologies and the most relevant system properties: resolution, dynamics and sensitivity.
Key concepts: 1. Imaging, 2. Systems

I – Components of the Assessment

LABORATORY – 35%	PROBLEMS – 15%
➢ Instrument implementation: microscopes, telescopes ➢ Image formation of point objects. Ideal imaging. Aberrations. Impact of stops ➢ Diffraction and Fourier optics. Spatial frequency spectrum. Spatial filtering ➢ Radiometry	➢ A set of 20 problems will be made available ➢ Students are required to deliver half (10) until the last course
ESSAY – 40% (inc. Simulation) - examples	**PARTICIPATION – 10%**
➢ Microscopes: STM, AFM, SNOM, SEM, fluorescence, multiphotonic, ... ➢ Telescopes: single aperture, multiple aperture, radio telescopes, ... ➢ Coherent or 3D imaging: interferometric imaging, OCT, SAR, holography, stereoscopy, ... ➢ Ultrasound imaging: medical, nondestructive testing (NDT), ... ➢ Medical imaging (non nuclear): X-ray radiology, computed tomography (CT), mammography, magnetic resonance imaging (MRI), ... ➢ Nuclear medicine imaging: PET, SPECT, ... ➢ Molecular imaging (Optics & Photonics News, December 2016, p. 37) ➢ Remote sensing: optical, radar, radiometers, spectrometers, imagers (spectroradiometric, spectropolarimetric, imaging spectrometers, ...), ➢ Spectral sensing: thermal, multispectral, hyperspectral, ... ➢ Photographic systems: film, digital photography, metrology and inspection imaging, ... ➢ Imaging for metrology, biometry, inspection, surveillance, autonomous navigation, human-computer interface (HCI), ... ➢ Light field imaging: Lytro (focus after shooting), ... ➢ Virtual / extended / augmented reality systems (Lumus, ...) ➢ Security imaging: [illegible], ...) ➢ Special support technologies for imaging: imaging sensors, adaptive optics, [illegible], scanning systems, stabilization, super-resolution, [illegible] FOV techniques ([illegible]), ...	➢ Individual short presentations on interesting topics (15 minutes each) ➢ Attendance of >= 80% of classes

Relative weights may change by +/- 5%.

II – Laboratory reports

The aim of the laboratory reports is to objectively describe each of the experiments carried out, identifying the materials and methods used, the schematic and functional representation of the experimental setup and the results, according to what is requested in the work plan - which will be distributed in advance.

For a better understanding of each work, the following guidelines should be followed when writing the reports:

1. Brief introduction to the subject, with the theory and mathematics relevant to the analysis of the results
2. Explanation of methods and materials / systems used
3. Overview of the results and suitable analysis (in relation to the underlying theory)
4. Conclusions, well supported by the analysis
5. References or bibliography identified
6. Activities common to several experiments (e.g. characterization of the lenses used) should be addressed in annexes

Evaluation will also address:

- ➢ The language used and quality of the information
- ➢ Critical thinking and clear separation between observations and interpretations (based on theory or explanatory hypotheses).

Experiments may be carried out in groups of 2-3 students, at most, with a common laboratory report. The participation of each student in the experiments will be taken in consideration.

Bibliography (examples)

Concepts

Hecht E, Óptica (Gulbenkian, 1998)

Bass M et al., Handbook of Optics (Vol 1-5), (OSA, McGraw, 2001, 2009)

Guenther R, Steel D, Encyclopedia of Modern Optics (Vol 1-5) (Elsevier, 2018)

Goodman J W, Introduction to Fourier Optics (Roberts & Co, 2005)

Goodman J W, Statistical Optics (2nd ed.) (Wiley, 2015)

Industry / Strategy

Photonics[21] - Europe’s age of light! How photonics will power growth and innovationvision paper (2017)

Lasers

Verdeyen J.T., Laser electronics (3ed., PH, 1995)

***

Internet resources

***

Revistas científicas

Revistas e artigos de revistas da Optical Society of America (OSA), SPIE e Nature Photonics

Sociedades científicas

Optical Society of America

SPIE – Society of Photoelectronics Industrial Engineers ***

Light instruments / systems are used for:

- Sources and detectors
- Mapping (2D or 3D fields)
- Meteorology
- Medical & biomedical
- Metrology
- Inspection
- Microscop(y)(ies)
- ...

- Astronomy
- Security, Biometrics, Security and surveillance
- Photography, Video, Film
- Military
- Vision enabling / emulators in (semi)automatic systems
- Probing
- Light concentration
- Materials characterizations
- …

Light observables are:

- Spatial distributions of irradiance → images
- Spectra
- Phase distributions
- Polarization
- Coherence

Systems using light can be:

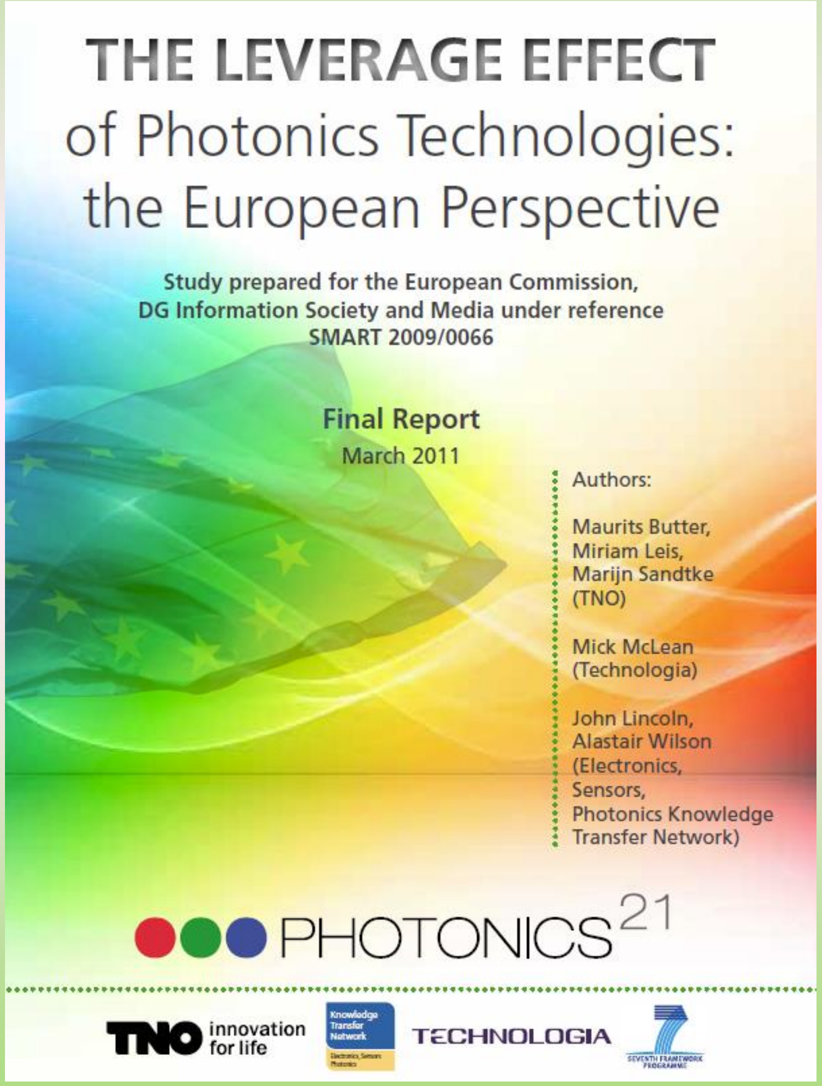
- Active / passive
- Static / scanning
- Monolithic / multi-aperture / interferometric imaging
- Monochromatic / multispectral / hyperspectral (frequency range)
- Intensity / phase (coherency) / polarization / wavelength sensitive
- 2D or 3D
- Imaging / non-imaging
- Radiometers, spectrometers, imagers (spectro-radiometers, imaging spectrometers, ...
- Built with devices from the nanoscale to the macro-scale

… and are characterized in terms of:

- **Intrinsic parameters**
  - Resolution (PSF, MTF)
  - Sensitivity
  - Dynamic range
  - Field of view (FOV) / Field of regard (FOR)
  - Depth of focus
  - Space-variant / space invariant properties (aberrations)
  - Sampling (spatial / dynamic / temporal)
  - ...
- **Operational parameters**
  - Quantization
  - Rates (pixel, frames, ...)
  - Integration time control
  - Noise reduction mechanisms
  - Stabilization
  - Signal handling and interfaces
  - Signal & image processing (on-chip, external)
  - Reconstruction techniques
  - Coding / compression
  - ...

Photonics21 - http://www.photonics21.org

*"**Photonics is the science of the harnessing of light.** Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation, and amplification, and most importantly, its utilisation for the benefit of mankind."*



Photonics

*“**Photonics is the science of the harnessing of light.** Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation, and amplification, and most importantly, its utilisation for the benefit of mankind.”*

Photonics is an area of study that involves the use of radiant energy (such as light), whose fundamental element is the **photon** . Photonic applications use the photon in the same way that electronic applications use the electron. Among the large number of current or possible photonic applications are: photonic switching, photonic networks, the photonic computer.

Photonics is one of the fastest growing **high-tech industries** in the world today. It includes:

- optical communications (e.g., fiber optics, lasers, and infrared links),
- **optical imaging (e.g., spy and weather satellites, night vision, holography, flat screen display, and CCD video cameras),**
- optical data storage and optical computing (e.g., CD’s and DVD’s),
- optical detectors (e.g., supermarket scanners, medical optics, and nondestructive evaluation of materials),
- lasers (e.g., welding lasers, laser surgery, laser shows, and laser rangefinders)
  spectroscopy (e.g., chemical and biological detection, anti-terror detection)
- quantum optics (e.g., quantum teleportation, quantum cryptography, and single-photon optics)

Readiness Levels

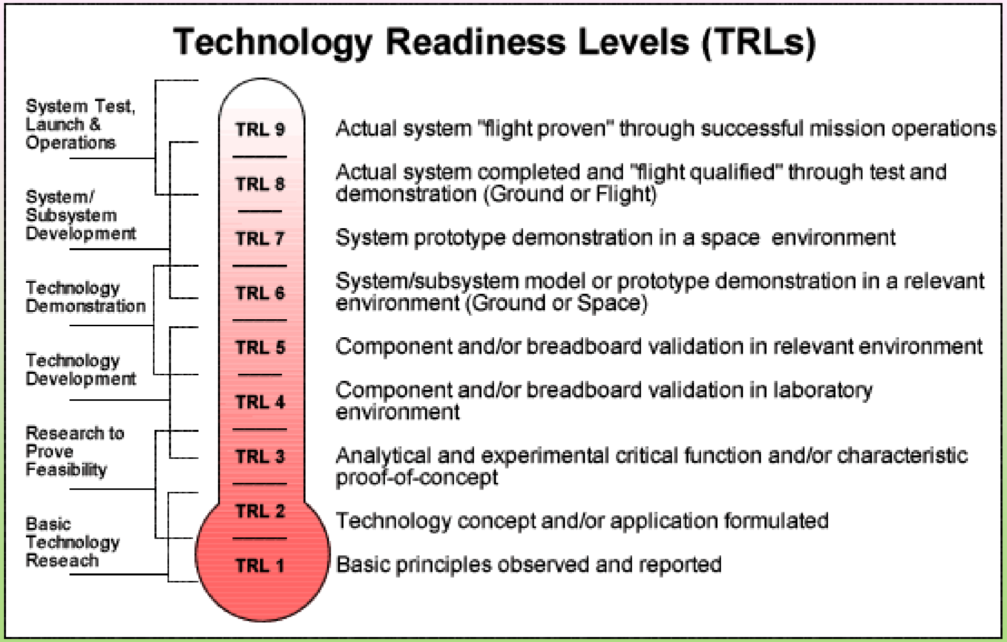
- **Technology Readiness Levels**
  - NASA (1995), DoD, …, H2020
  - https://en.wikipedia.org/wiki/Technology_readiness_level
  - https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf
  - https://esto.nasa.gov/files/TRL_definitions.pdf
- **System Readiness / Maturity Levels**

Technology Readiness Levels (TRLs): Overview

TRLs are NASA-generated and Used Extensively by DoD

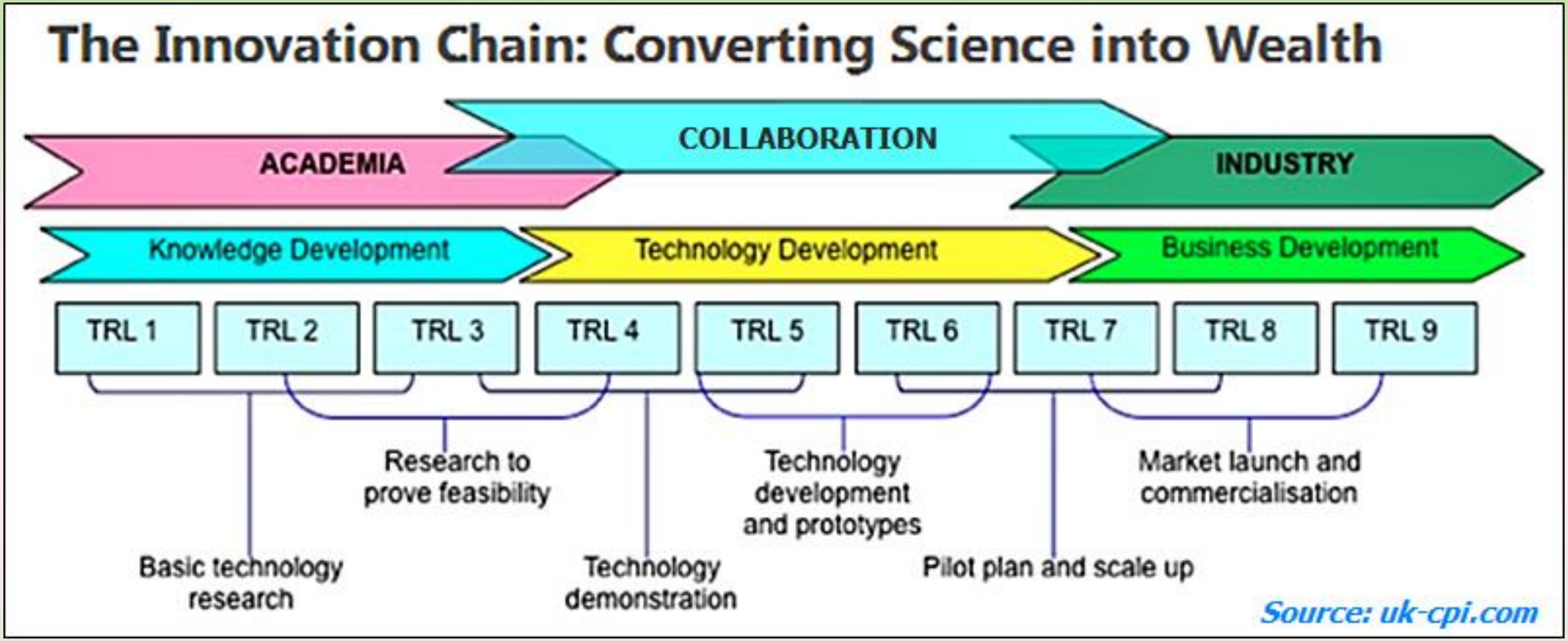
Basic principles observed and reported	1	Basic
Technology concept and/or application formulated	2	Basic
Analytical and experimental critical function and/or characteristic	3	Basic
Component and/or breadboard validation in laboratory environment	4	Advanced
Component and/or breadboard validation in relevant environment	5	Advanced
System/subsystem model or prototype demonstration in a relevant environment	6	Applied
System prototype demonstration in a operational environment	7	Applied
Actual system completed and 'flight qualified' through test and demonstration	8	Applied
Actual system 'flight proven' through successful mission operations	9	Applied

TECHNOLOGY MATURITY

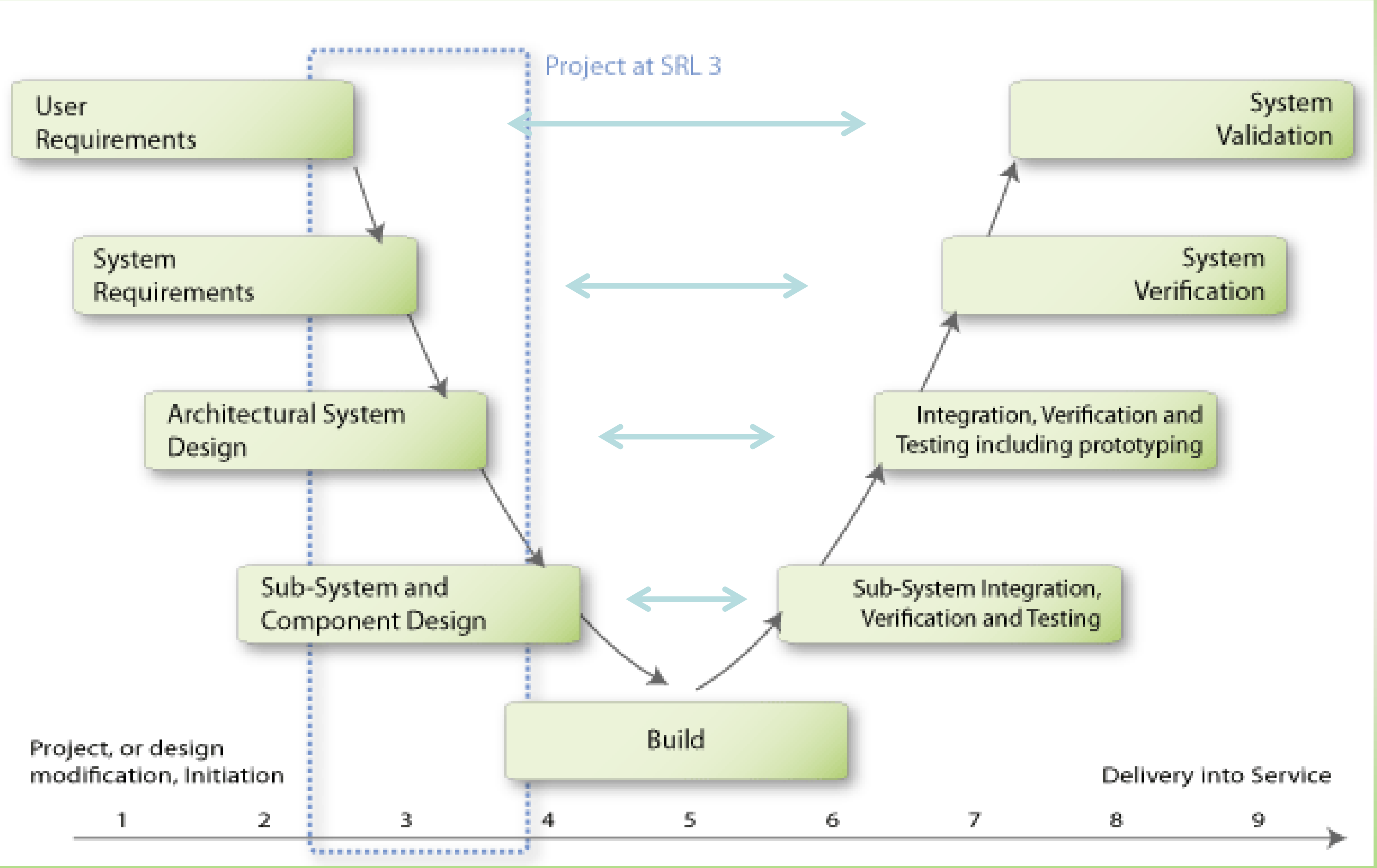


TRL		
	9	Commercialized
	8	Pre-production
	7	Field Test
	6	Prototype
	5	Bench / Lab Testing
	4	Detailed Design
	3	Preliminary Design
	2	Conceptual Design
	1	Basic Concept

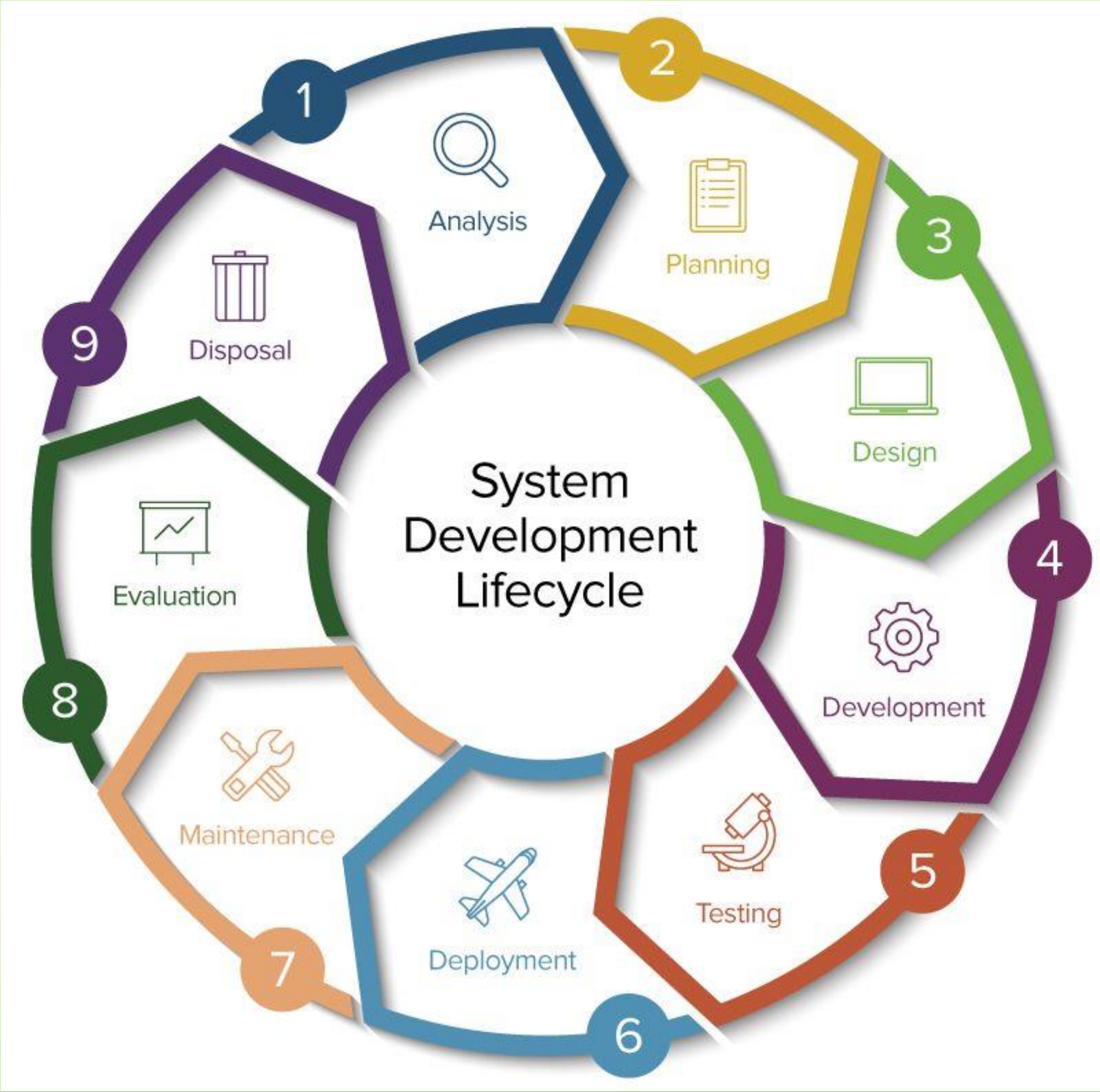
Innovation chain



System Readiness / Maturity Levels



System development cycle



https://www.smartsheet.com/system-development-life-cycle-guide