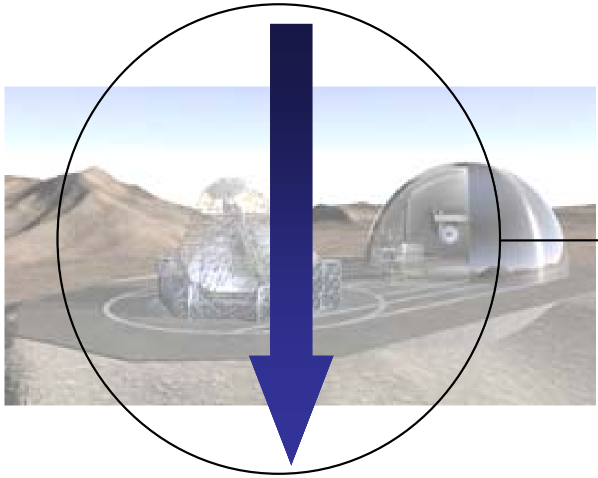
System Engineering

(Presented by P. Dierickx)

European Southern
Observatory

What is it ?

Top Level Requirements



System engineering

System engineering

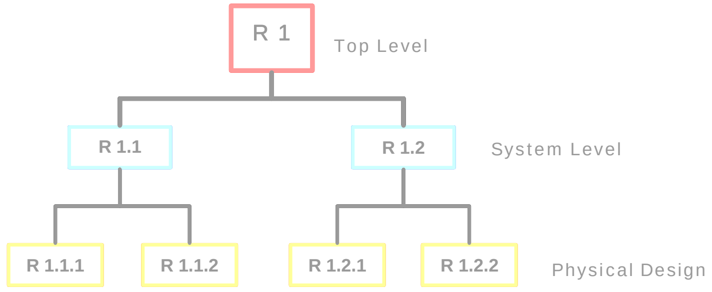
A structured approach towards design, analysis, verification, integration

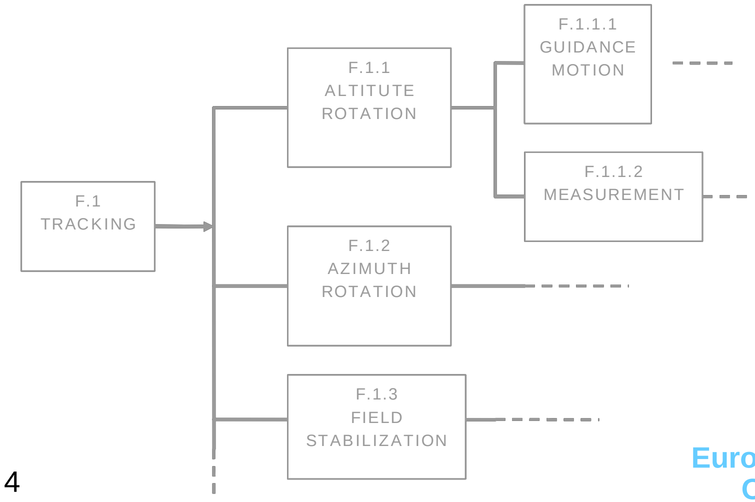
Methods
Standards
Requirements
Traceability
Configuration control
Disturbance characterization
Tools (design, modelling, etc.)
Interface management
Risk management
RAMS
(Reliability, Availability, Maintainability, Safety)

(According to Enzo)

Requirements

- Requirements must be verifiable
- Top Level
  - Science cases into structured numbers
  - Other factors: budget, schedule
  - Requirements, NOT solutions (but somewhat pre-emptive)
- Breakdown
  - Level-1 (system), including constraints & guidelines
  - Functional breakdown
  - System architecture
  - Product structure
  - Budgets (error, reliability, etc.)





Level 1 (current content)

Example

Star magnitude (v)	Seeing (arc seconds)	Wavefront RMS on-axis (μm)	Field of view (arc minutes, diameter)
Single-conjugate adaptive optics			
13.5	0.4	0.180	N/A
	0.6	0.200	N/A
	0.8	0.230	N/A
	1.2	0.300	N/A
15.5	0.4	0.274	N/A
	0.6	0.302	N/A
	0.8	0.344	N/A
Multi-conjugate adaptive optics			
13.5 (integrated over all guide stars)	0.4	0.252	3
	0.6	0.234	3
	0.8	0.302	3

Adaptive wavefront control quality requirements (IR AO)

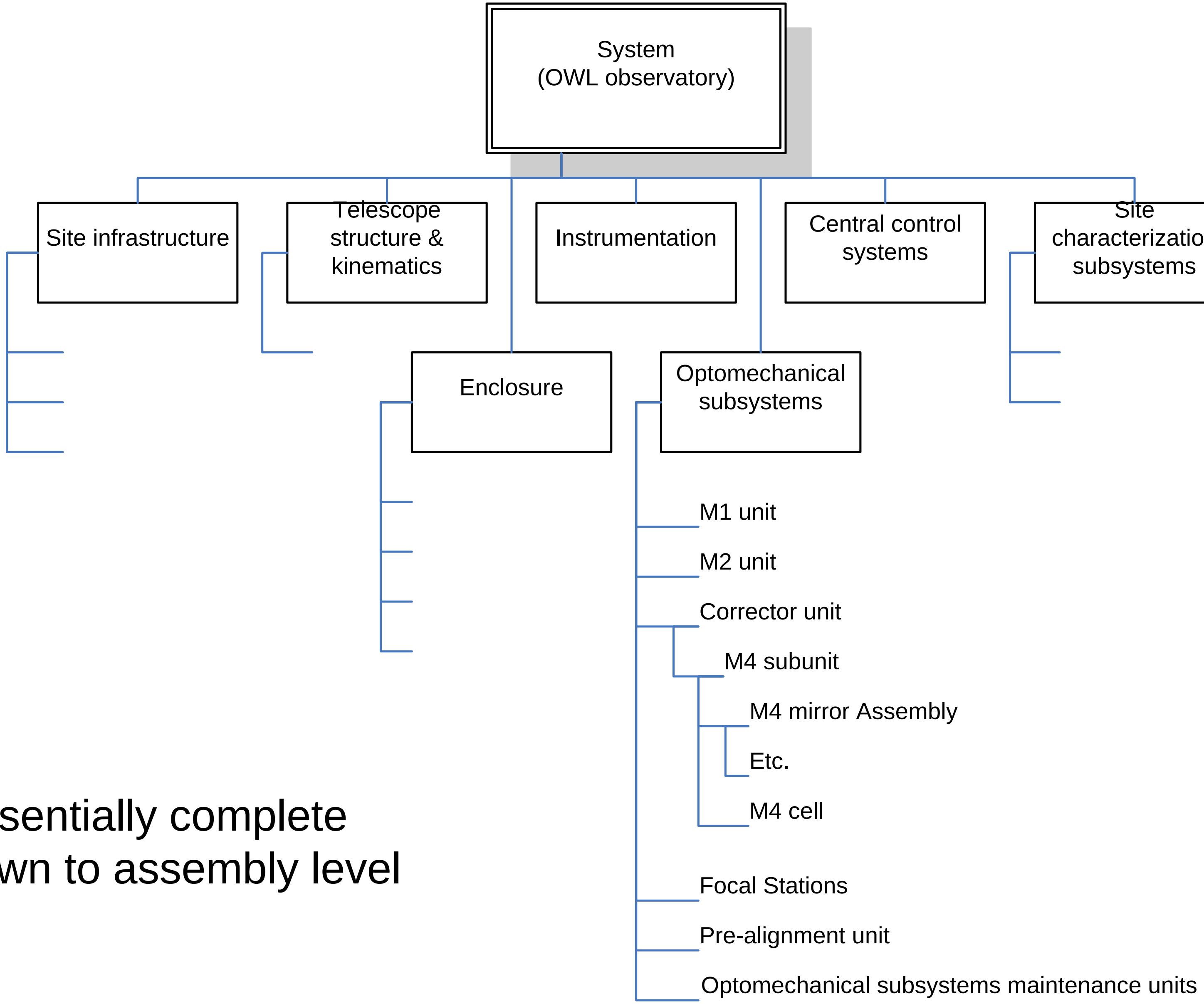
Failure / damage hierarchy

Cat.	Type	Definition	Max. probability or rate of occurrence
I	Catastrophic	*Complete loss of system or threat to personnel safety.* OR *Repair cost exceeds 10% of capital investment.*	0
II	Catastrophic	*System is out of operation for 2 months or more,* OR *Repair cost exceeds 5% of capital investment,* whichever comes first.	0.01% over 30 years
III	Critical	*System is out of operations for up to 2 months* OR *Repair cost exceeds 1% of capital investment,* whichever comes first.	0.05% over 30 years
IV	Major	System is out of operation for up to 1 calendar week.	Once every 10 years
V	Significant	System is not able to allow science time for up to 1 calendar week.	Once every 5 years
VI	Minor	System is not able to allow science time for 24 hours.	3 times per year

Design constraints and guidelines

- Reliance on proven technology, materials and processes, from design to operations
- Max. reliance on serial production or standard parts
- Max. development time for critical technology
- Start of science as soon as possible after first light
  - With negligible engineering overheads
  - reduced pupil area, single conjugate IR AO with NGS
- Progressive loss of performance in case of failure
- Operation and maintenance considerations
  - Minimize system integration and operational resources
  - Maintenance; minimize operational complexity
  - System integrity and safety of human resources.

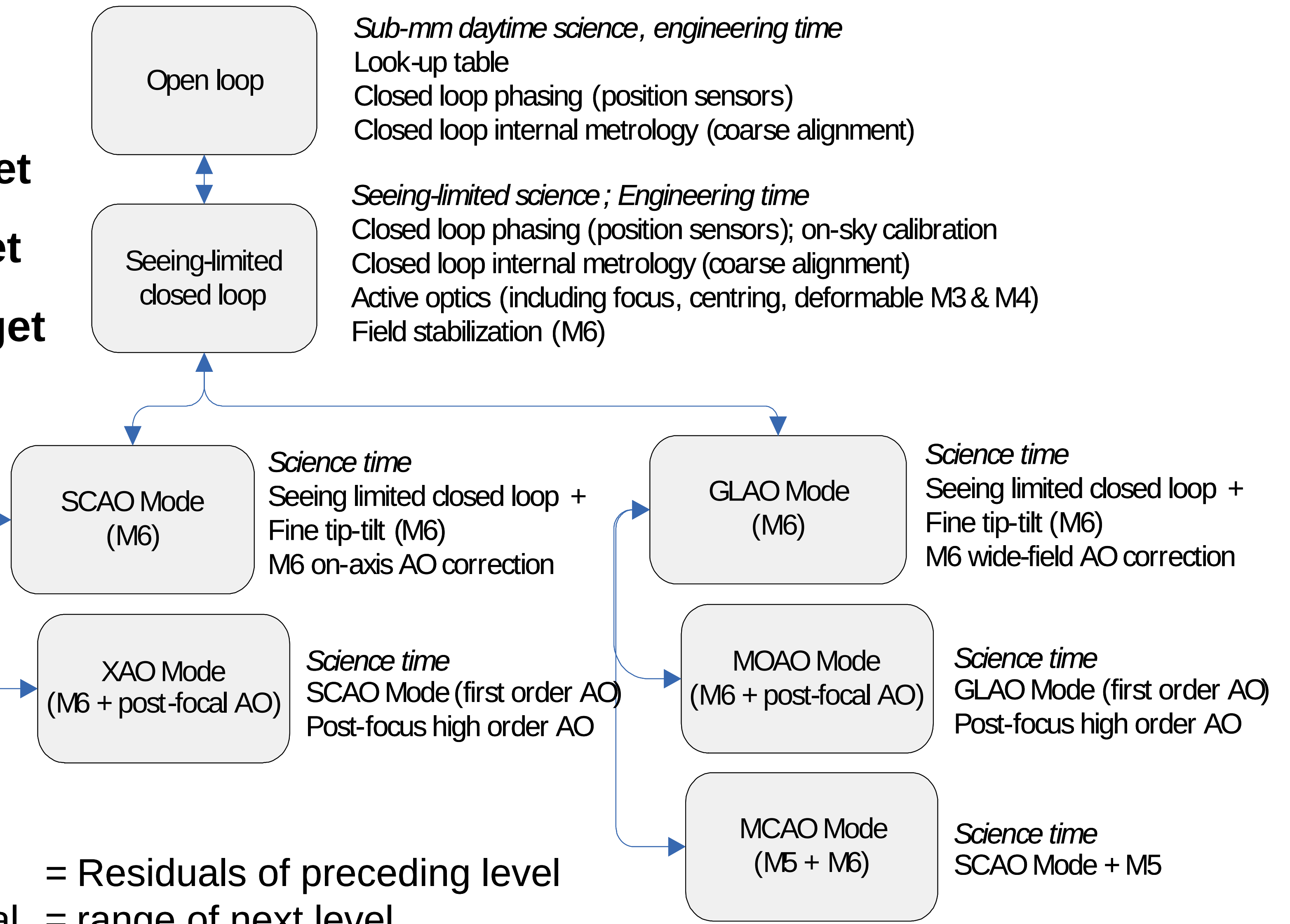
Product structure



Essentially complete
down to assembly level

Error budgets, offloading

+ **Pointing budget**
+ **Emissivity budget**
+ **Reliability budget**
+ **Availability budget**



Max. range = Residuals of preceding level
Max. residual = range of next level

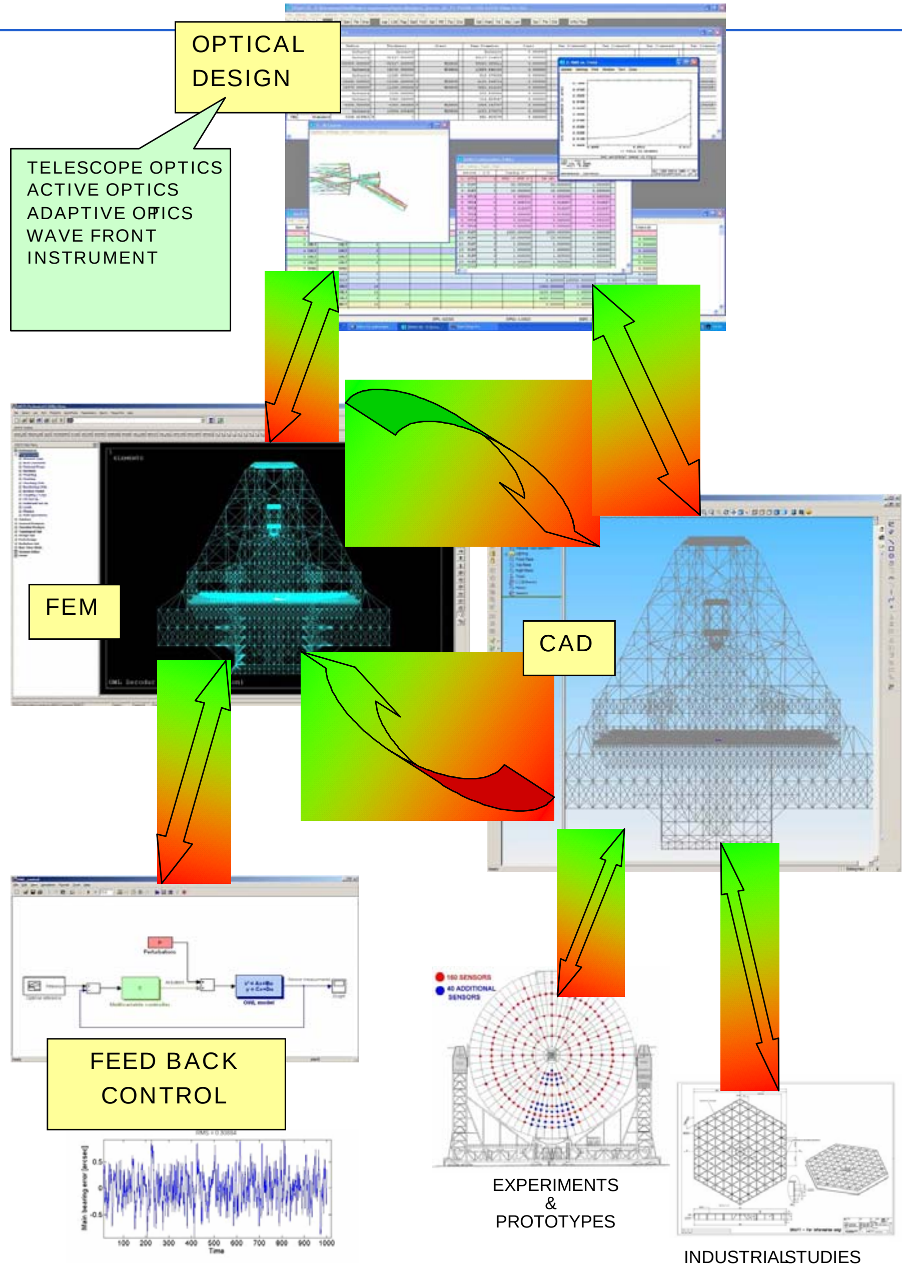
- Offloading
  Relax amplitude requirements
- Ensure near-optimal conditions

(In progress)

Tools

- Design tools
- Analysis tools
- Configuration management tools (e.g. DOORS(*))

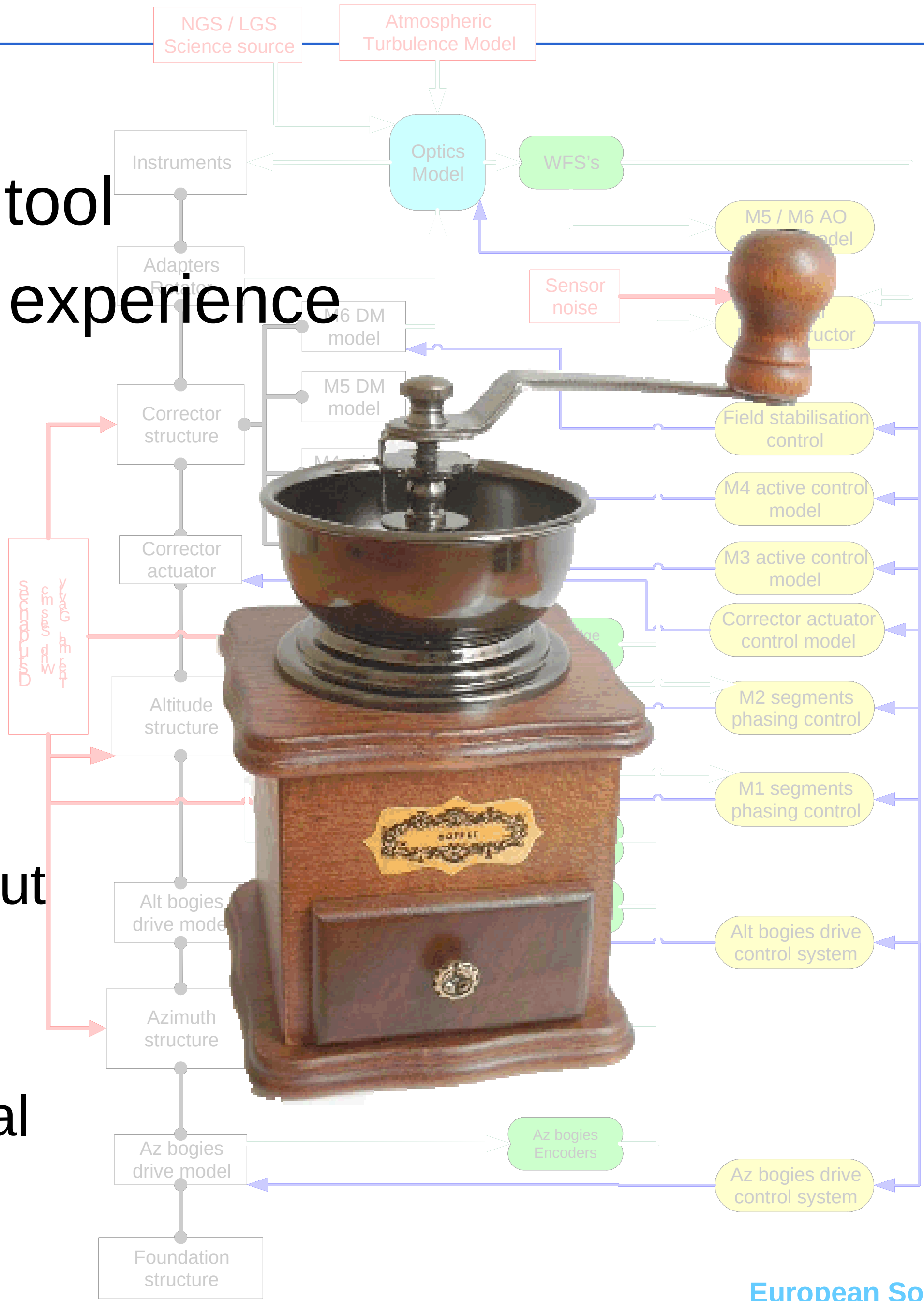
- Maximum reliance on internationally recognized software
- Interoperability
- Devolution



(*) Dynamic Object-Oriented Requirements System

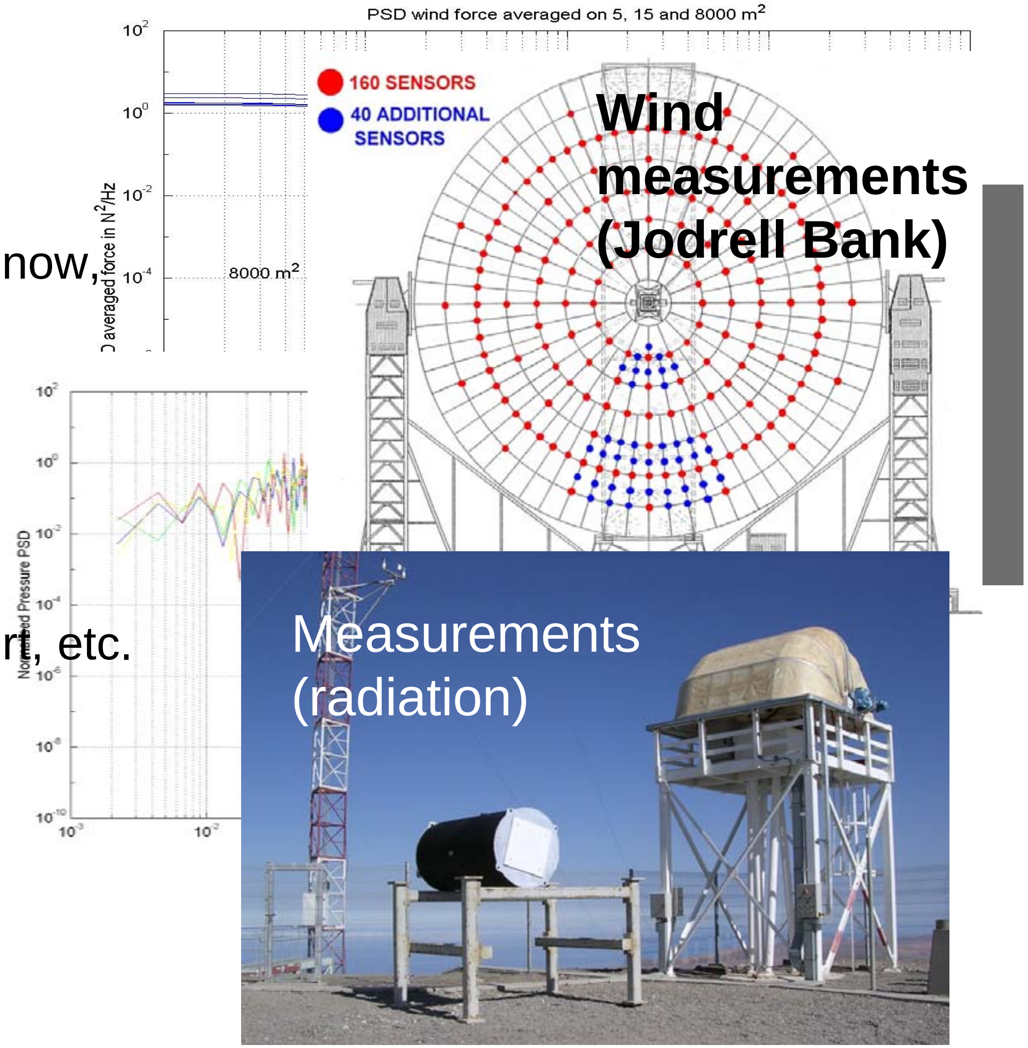
Integrated modelling

- A design and analysis tool
- Building on VLT/VLT-I experience
- Computing power
  - Use reduced models where appropriate
  - AO simulations already running
- And …
  - Output = processed input
  - Does not generate information
  - Quality of input essential



Disturbances (characterization, assessment)

- Environment
  - Wind
  - Atmospheric turbulence (AO)
  - Temperature, humidity, rain, snow, ice, dust, radiation
  - Microseismicity
- System Induced Disturbances
- Human induced disturbance
  - Camp, hotel, sewage, transport, etc.
  - Power generation
  - Light pollution
- Survival load cases
  - Earthquake
  - Wind
  - Temperature



Reliability, Availability, Maintainability, Safety (RAMS)

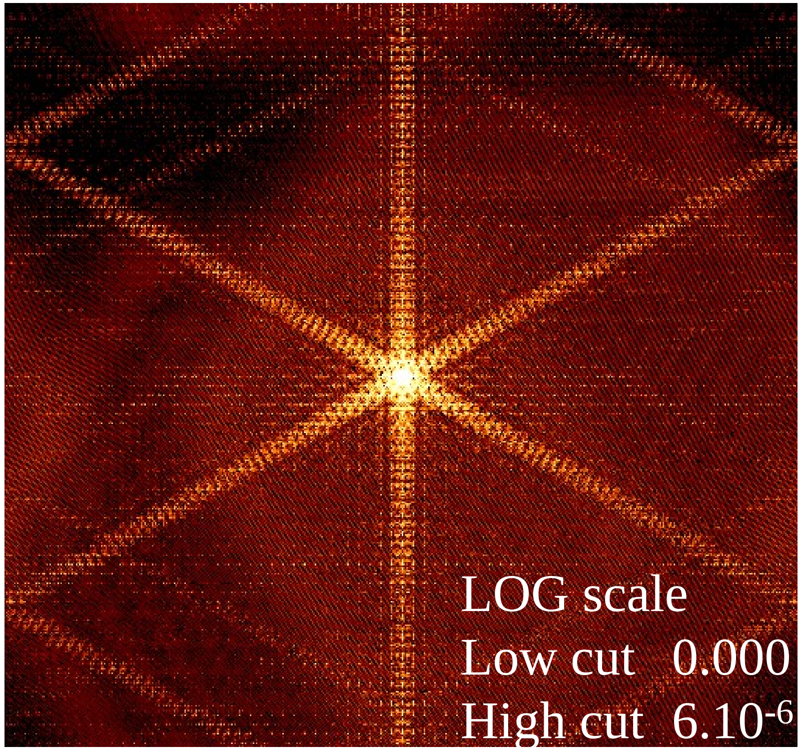
- Integral part of the design
  - Strong impact on system median performance
  - Strong impact on operations, maintenance
- Reliability and performance
  - A continuous *but planned* struggle
  - Diagnostics, logs, traceability
  - Extensive analysis (design phase)
  - Single Point Failure List
  - Modular design
    - Favours progressive loss of performance
    - Preventive & corrective maintenance
    - Parallelization
- Incorporated in concept design (e.g. segments maintenance requirements), analysis available in crucial areas (e.g. impact of phasing failures)

Phasing failures

Example

- M2, 3 faulty segments, 46 µm PtV piston + tilt
- λ=2.0 µm
- Segment size 1.5-m
- Seeing neglected
- Random piston + tip-tilt residuals 0.16 µm PtV

NB: effect much fainter with M1 (1 segment = 1/3000th of pupil)



Piston each faulty segment by 100 mm …