Real-time Simulation

for Adaptive Optics Real-time Control System Development

Andrew Reeves, Alastair Basden, Sebastian Durand, Florian Ferreira, Maxime Laine, James Osborn, Arnaud Sevin and the GreenFlash Team

Motivation: Computational Performance

- How fast can the RTCS be run?
  - Test the RTCS can run at required rate
  - Test the RTCS "jitter" – the variance in frame time
  - Need to throw data at the RTCS at real frame rates without needing to set up one or more WFS cameras
- Test that results still valid when running at full speed
- Want to determine the computational power required for a given AO system
- Want to do this *off-sky*!

Motivation: Algorithm development

- Ensure that the algorithm implemented for the real RTCS gives the expected results
  - Reconstructors, Centroiders, etc…
- May be different from when implemented in stand-alone simulation packages
  - Optimisations for computational performance could affect results
- Want to test algorithm parameters with real RTCS interfaces

Motivation: Interface development

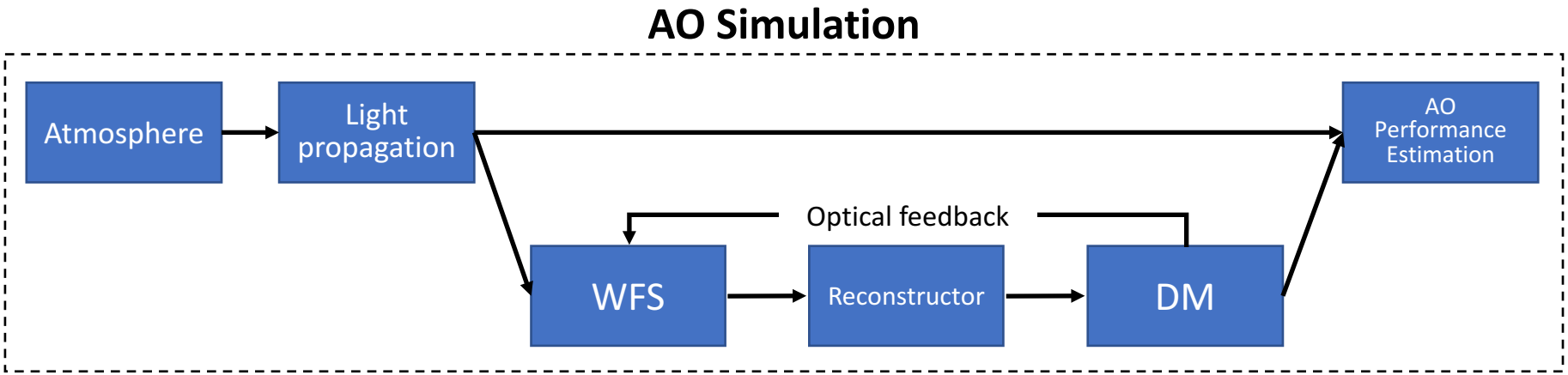
- AO systems have become more with multiple WFSs and DMs, tomography and predictive algorithms
- Can use a ”real-time” simulation to develop user interfaces to control these features
- Can develop automated parameter optimisation techniques
- Develop the on-sky ready user interfaces well in advance of deploying the AO system

Implementation

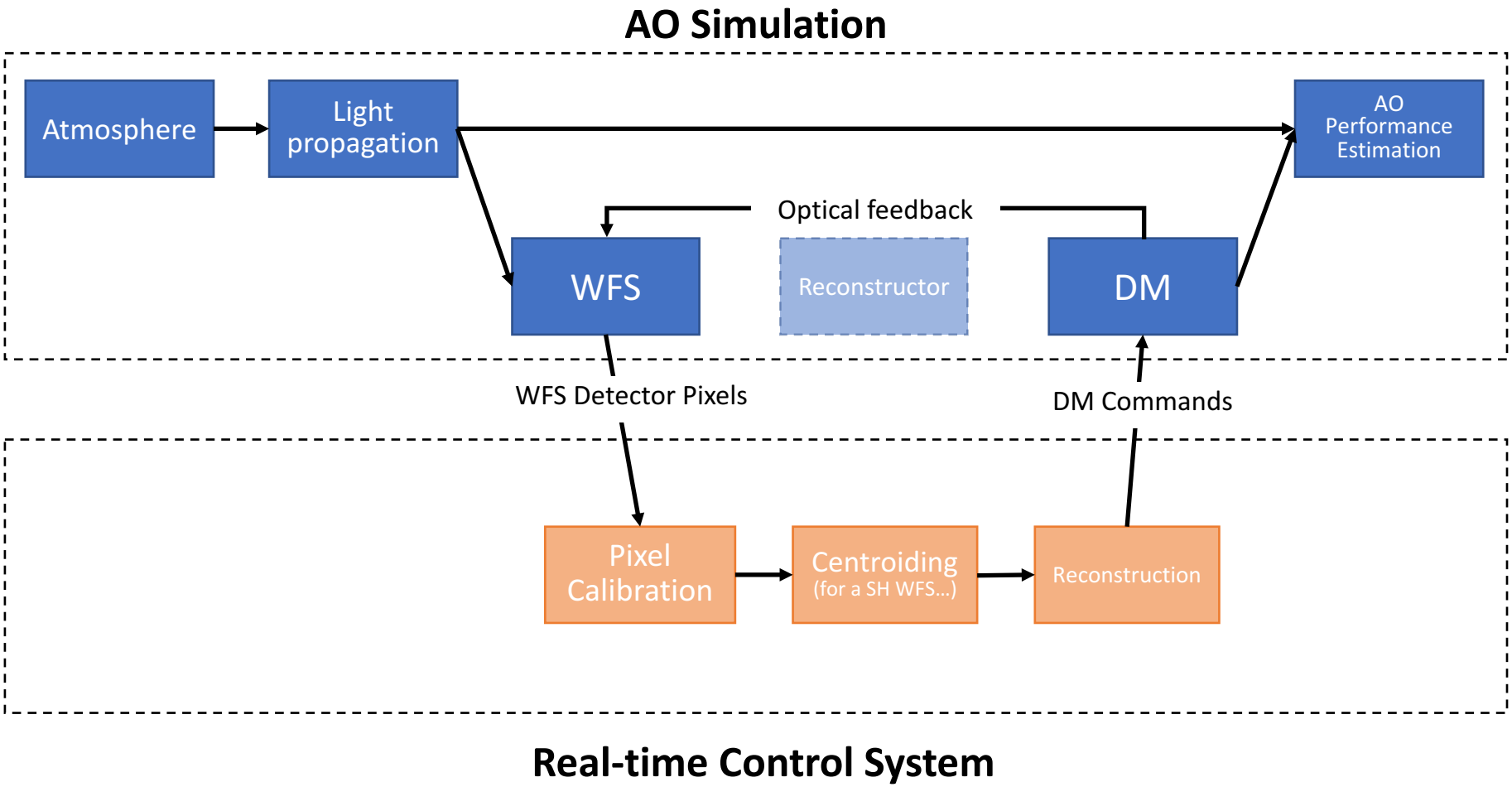
- Two main solutions:
- Interface End-to-end simulation to RTCS
  - Use existing AO simulation package to pass WFS data to RTCS
  - Simulation received DM commands and evaluates AO performance
  - (May not run a on-sky frame rates)

- FPGA based camera simulator
  - Deterministically send pixels to the RTCS at very fast rate
  - FPGA can operate at high frame rate with very low jitter
  - (WFS data may not be realistic, and cannot accept DM feedback)

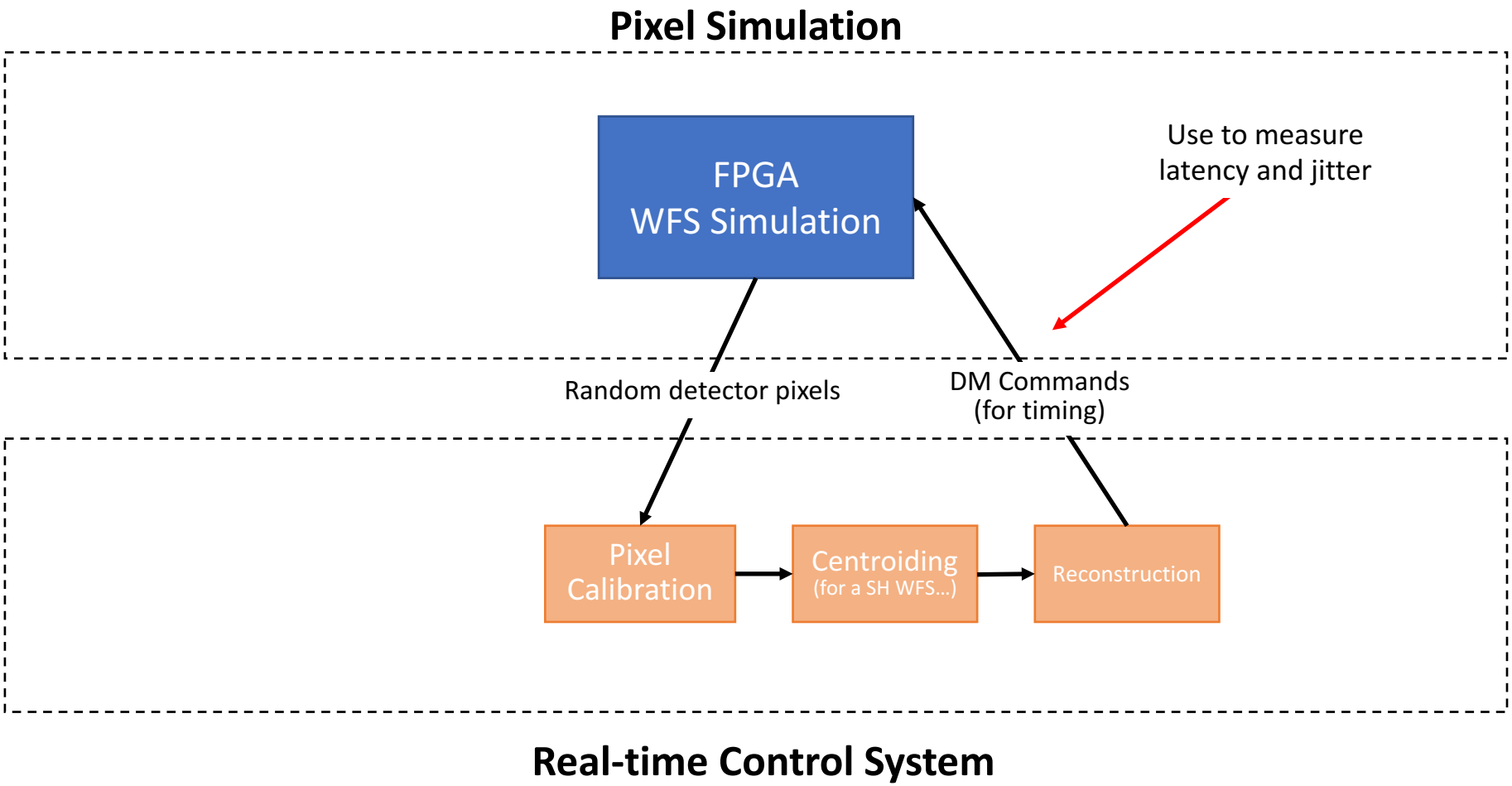
End to End Simulation



End to End Simulation



FPGA WFS Simulation

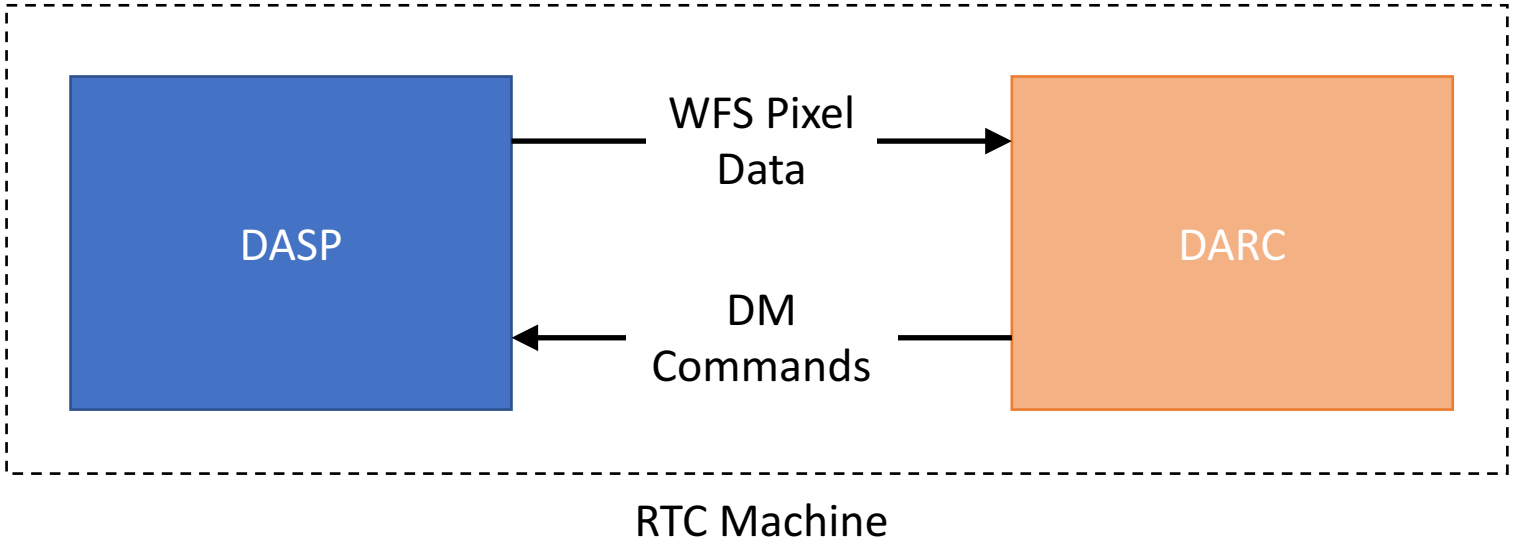


DARC/DASP

- DARC – Durham Adaptive Optics Real-time Controller
  - On sky RTCS powering the CANARY tomographic AO demonstrator
  - Also used in Durham laboratory bench, DRAGON and under evaluation for facility AO system at GTC
  - Supports multiple WFSs, multiple DMs, tomographic AO reconstruction, multiple centroiding schemes, predictive AO control, etc…
- DASP – Durham Adaptive optics Simulation Platform
  - Mature AO simulation capable of ELT scale operation
  - Highly parallelised for multi-threaded CPU operation
- (Work mainly performed by Alastair Basden)

DARC/DASP

- DASP Sends WFS data to DARC
- DARC returns DM Commands to DASP
- Both operate on same machine, passing data through shared memory



DARC/DASP

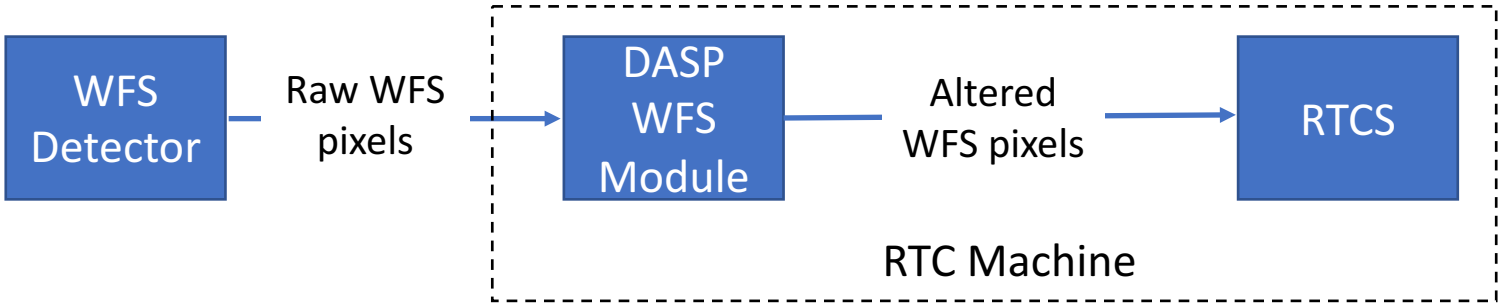
- Used heavily for development of the CANARY AO demonstrator
  - Reconstructor development (Tomography, CuReD)
  - User interface development

- DASP simulates:
  - 3 7x7 NGS WFS + 1 14x14 “truth” WFS
  - 4 14x14 LGS WFS
  - 7x7 figure Sensor + 14x14 figure Sensor
  - 2 TT DMs
  - 1 8x8 actuator DM + 1 15 x 15 actuator DM

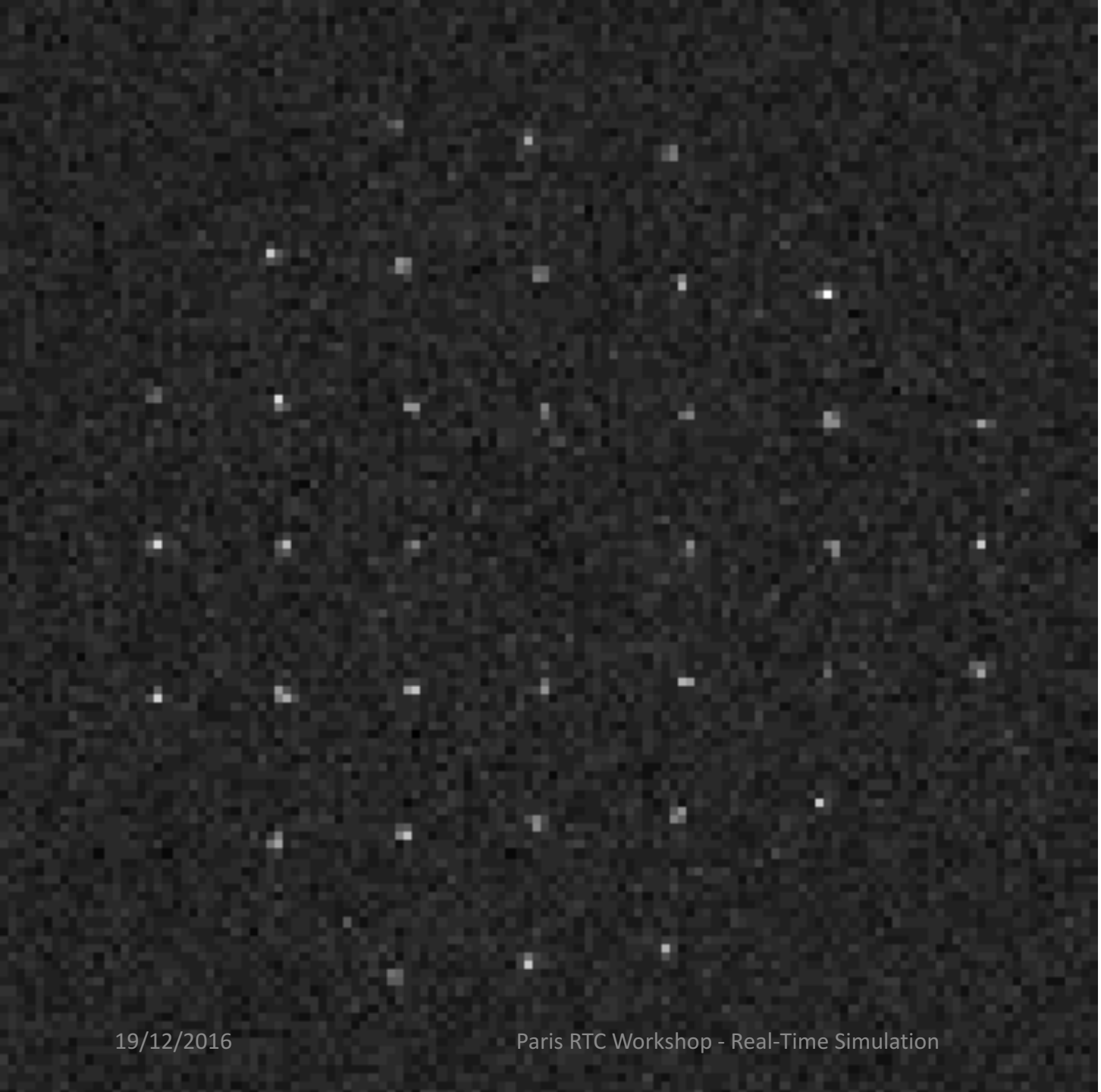
- DARC can switch seamlessly between bench data from CANARY and simulated data from DASP

SH WFS Spot modification

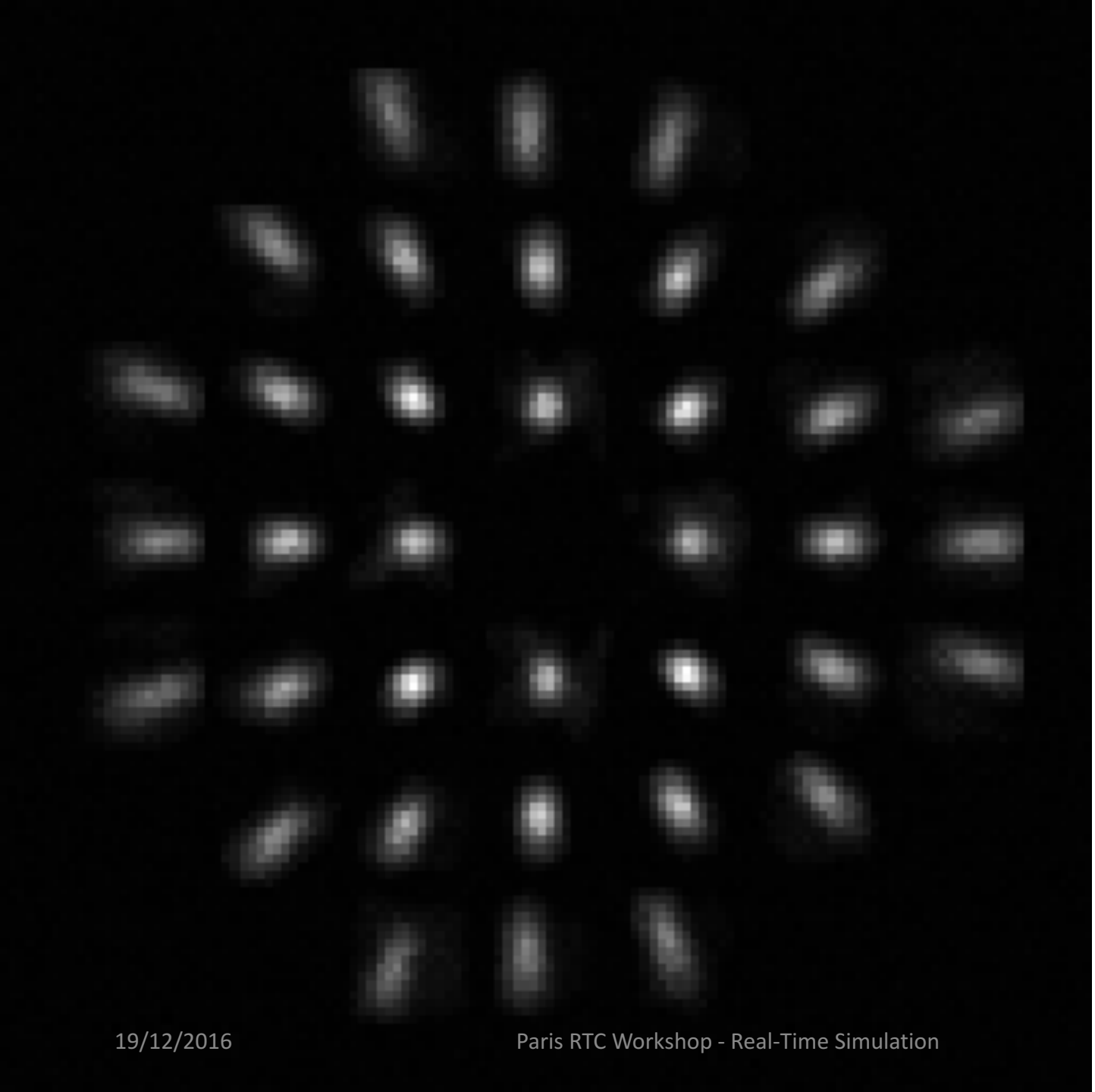
- Use DASP's WFS detector simulation modules to alter real WFS images



- Change NGS to LGS



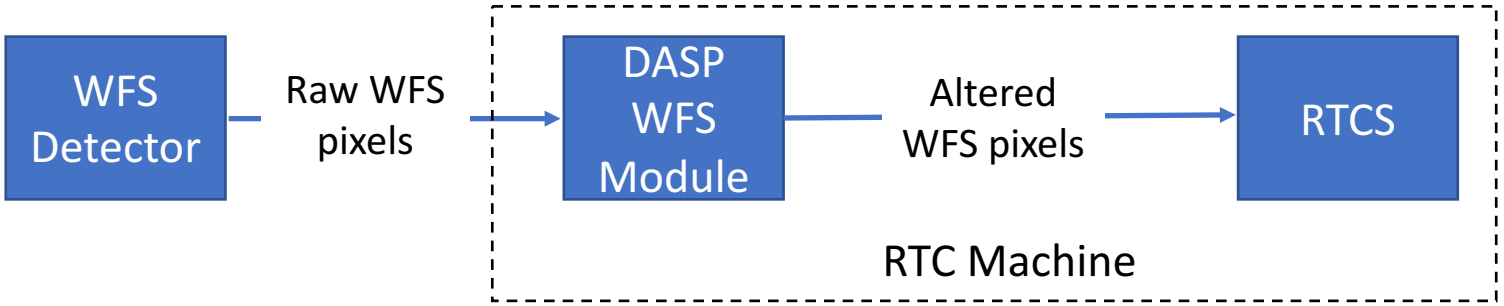
Raw NGS WFS image from real camera



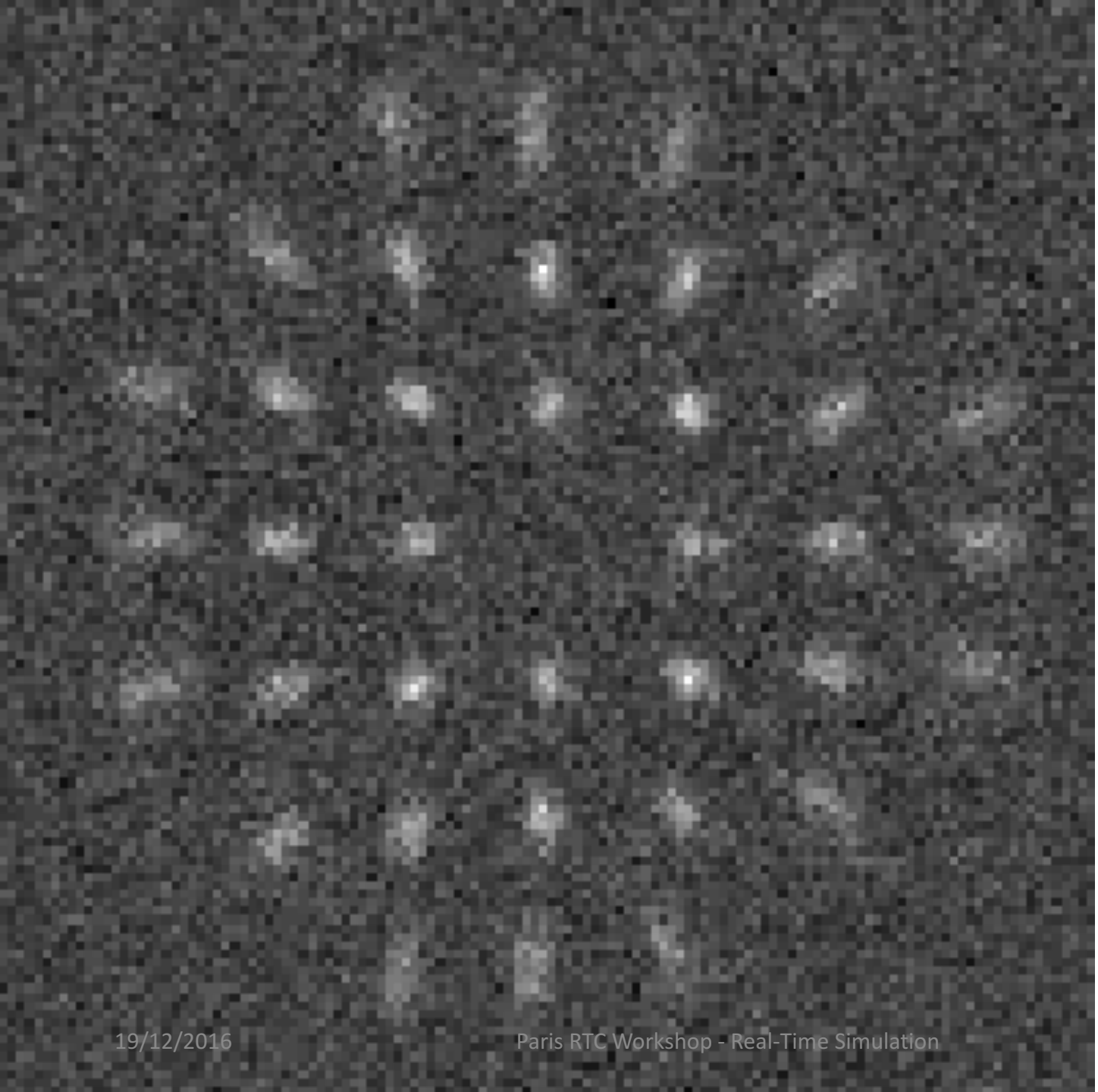
Simulated LGS elongation

SH WFS Spot modification

- Use DASP's WFS detector simulation modules to alter real WFS images



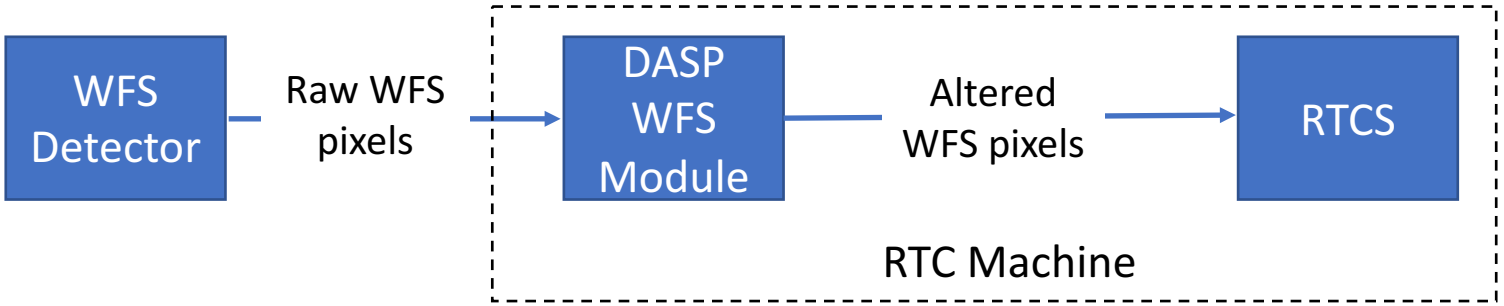
- Swap NGS to LGS
- Alter noise parameters and LGS profile



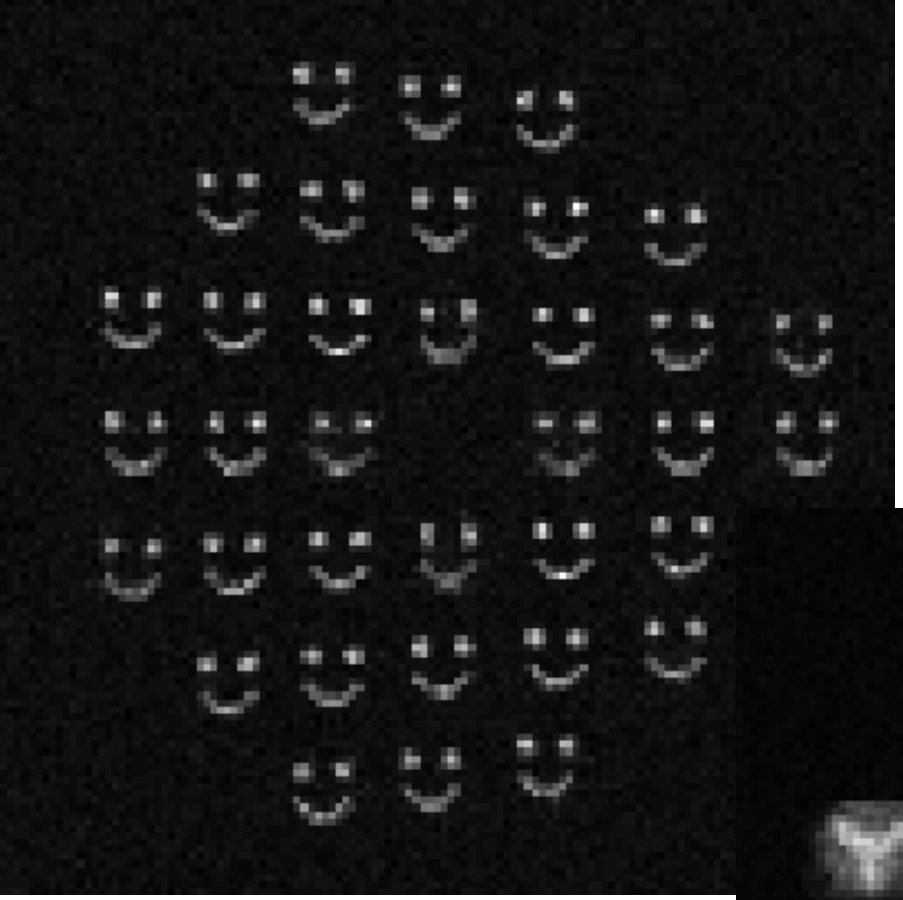
Alter noise parameters

SH WFS Spot modification

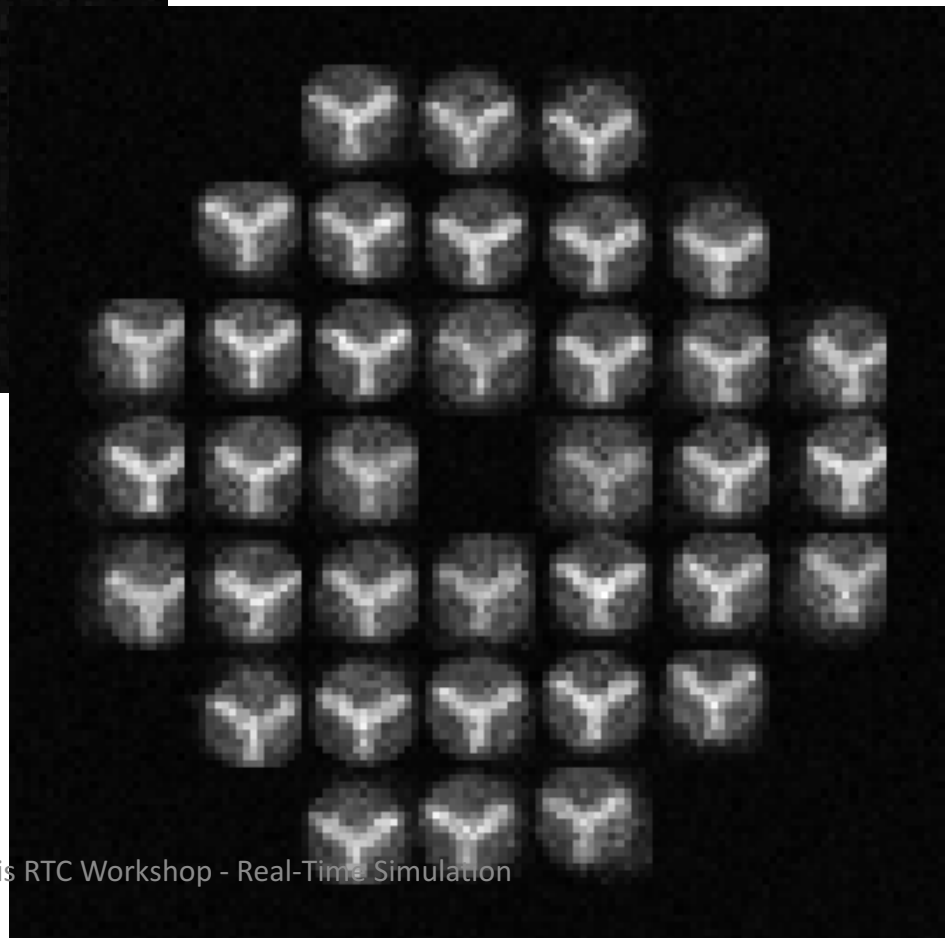
- Use DASP's WFS detector simulation modules to alter real WFS images



- Swap NGS to LGS
- Alter noise parameters and LGS profile
- etc…

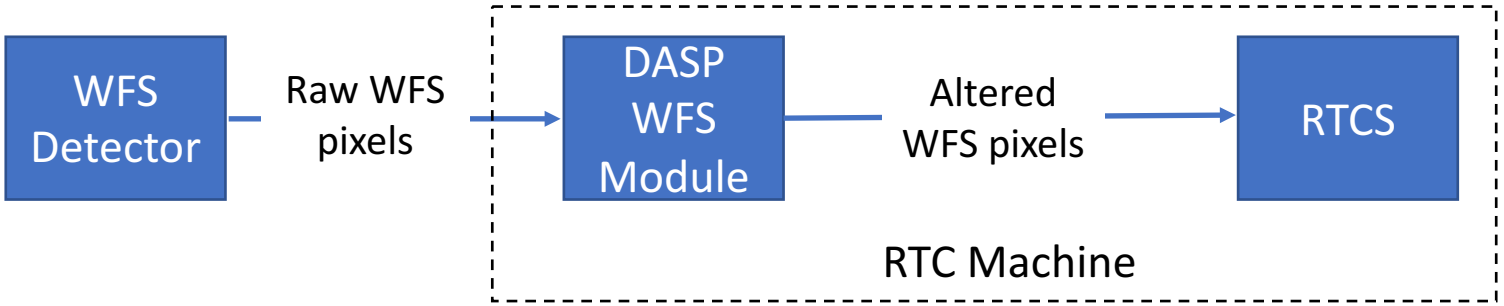


Etc….



SH WFS Spot modification

- Use DASP's WFS detector simulation modules to alter real WFS images



- Swap NGS to LGS
- Alter noise parameters and LGS profile
- etc…
- Useful for developing algorithms and UI's for correlation and match filtering WFSing techniques

DARC/DASP

- SH WFS Spot modification

- Use DASP's WFS detector simulation modules to change real WFS images
  - Change NGS to LGS
  - Alter noise parameters and LGS profile
  - etc…
  - Been useful in developing algorithms and UI's for correlation and match filtering WFSing techniques

GreenFlash

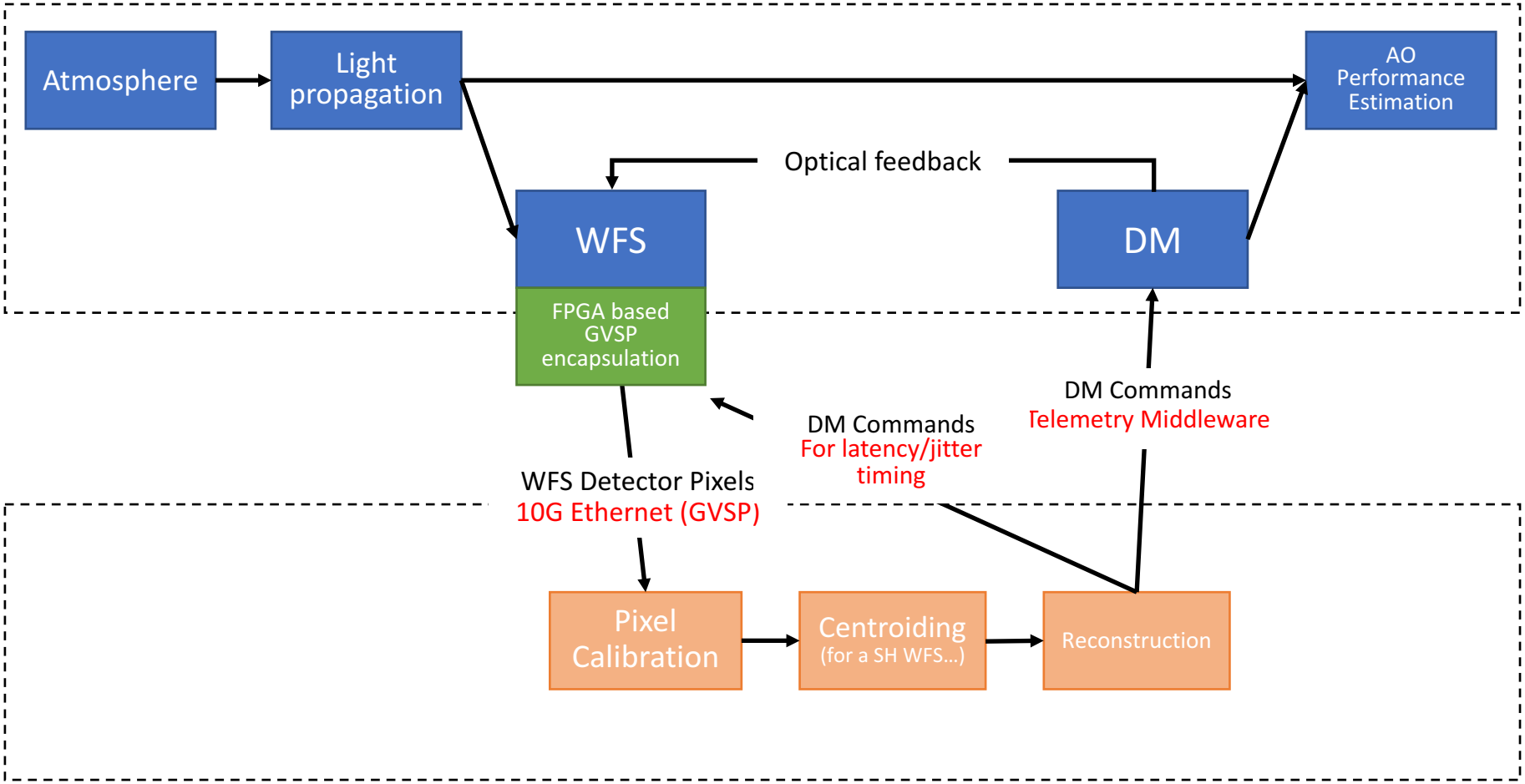
- Project to investigate and develop new and emerging high performance computing technologies for AO on ELTs
- Requires a real-time simulator to test the RTC prototypes
- Want to test computational performance and aid algorithm development
  - Simulator must be capable of providing a closed loop AO simulation.
  - Simulator requires a ”fast mode”, running at real-time rates of up to 1kHz
- Currently in design stage, moving to a prototype over the next year

GreenFlash: "Simulation Rate Mode"

- COMPASS GPU based simulation used as end-to-end AO simulation
- WFS data passed immediately via FPGA frame timer to the RTCS
  - Data encapsulated as GigeVision Streaming Protocol
- DM commands received and used as input to simulated DM
- Runs at up to ~800Hz for VLT, 100-200 Hz for ELT scale simulation (currently SCAO)
  - Aim to increase speed to "real-time" rates for ELT's in the long run
- Prototyping currently in LESIA, Paris

GreenFlash:
"Simulation Rate Mode"

AO Simulation – COMPASS on GPU



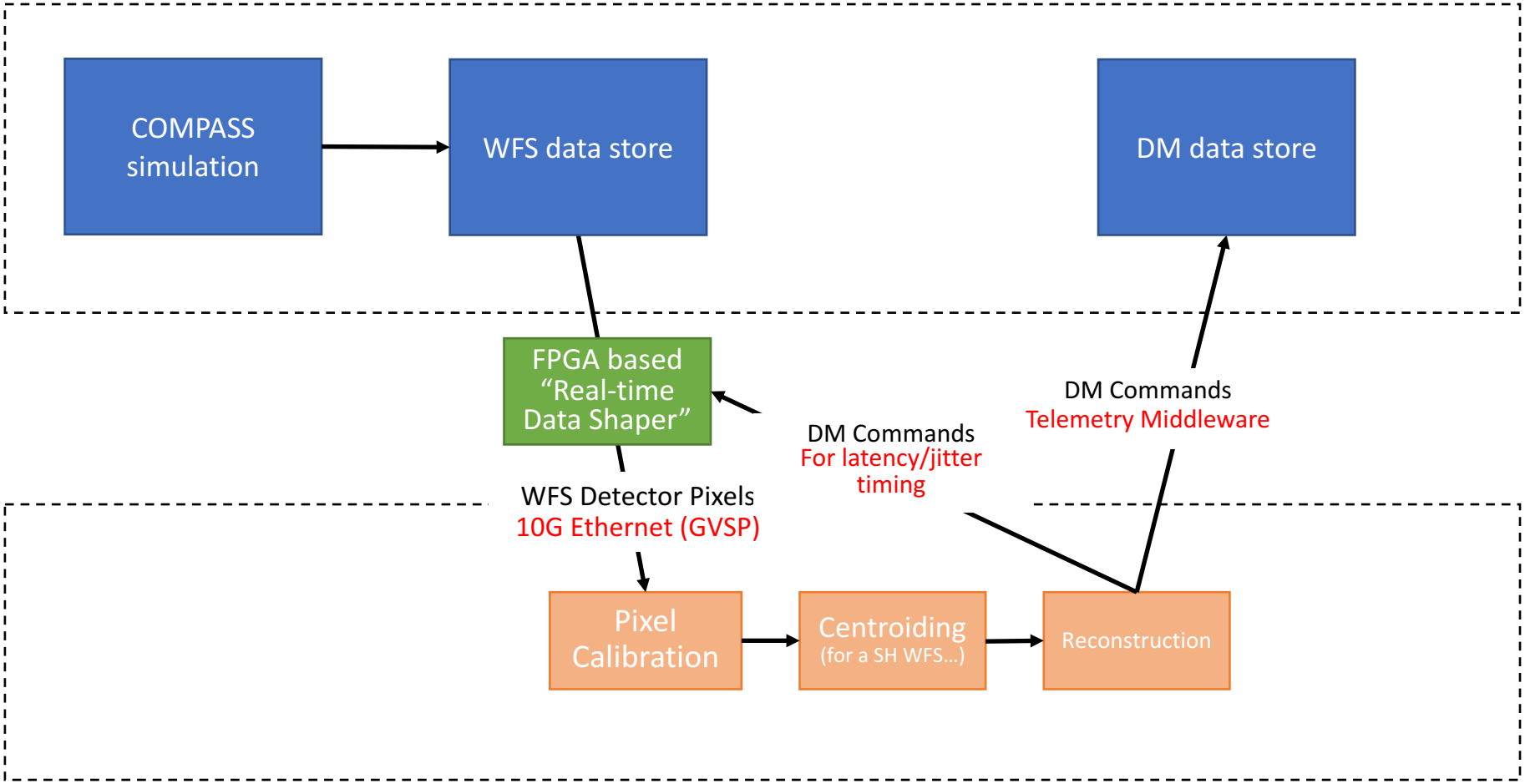
GreenFlash RTCS

GreenFlash: "Fast Mode"

- Want to send data at ~1KHz for prolonger period with minimal jitter
- Multiple WFSs required, up to MAURY E-ELT scale simulation
- COMPASS used to generate large store of WFS data
- WFS data encapsulated as GigeVision Streaming Protocol
- WFS sent via FPGA based "real-time data shaper" to RTCS
- DM commands send to same FPGA to time latency and jitter of RTCS
  - DM data also saved for later analysis

GreenFlash: "Fast Mode"

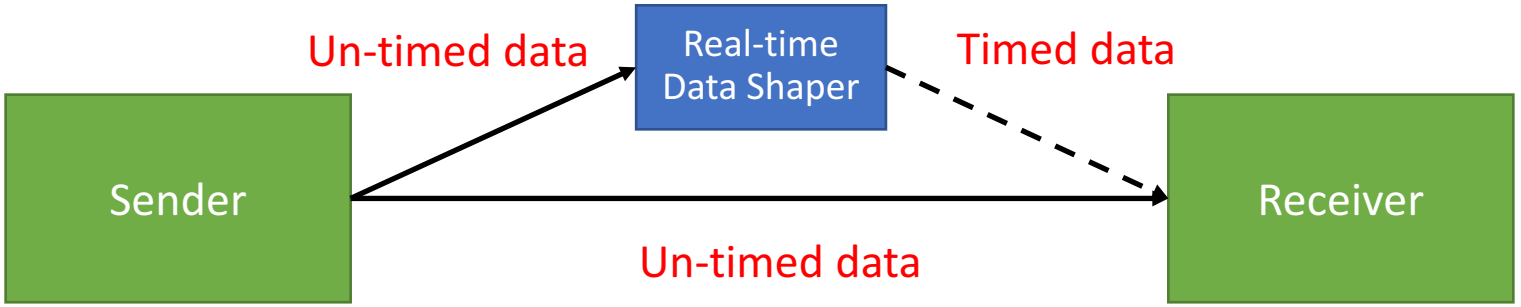
AO Simulation – COMPASS on GPU



GreenFlash RTCS

FPGA based "Real-time Data Shaper"

- An FPGA board with two 10G Ethernet ports
- Transparent to sender and receiver
- Intercepts and buffers UDP packets sent via a given port
- Re-sends data with an accurately timed gap between frames
  - No jitter – just like a real camera
- Can "drop-in" to existing 10G link to add timing



Summary

- Real-time simulator is useful for RTCS development!
  - Computational performance evaluation
  - Algorithm and interface development

- DARC/DASP is a working example of the technique and has already proven very useful within the CANARY project

- GreenFlash will make use a real-time simulator
  - “Simulation rate” mode, offering closed loop AO simulation
  - “Fast mode” offering full ELT frame-rate performance