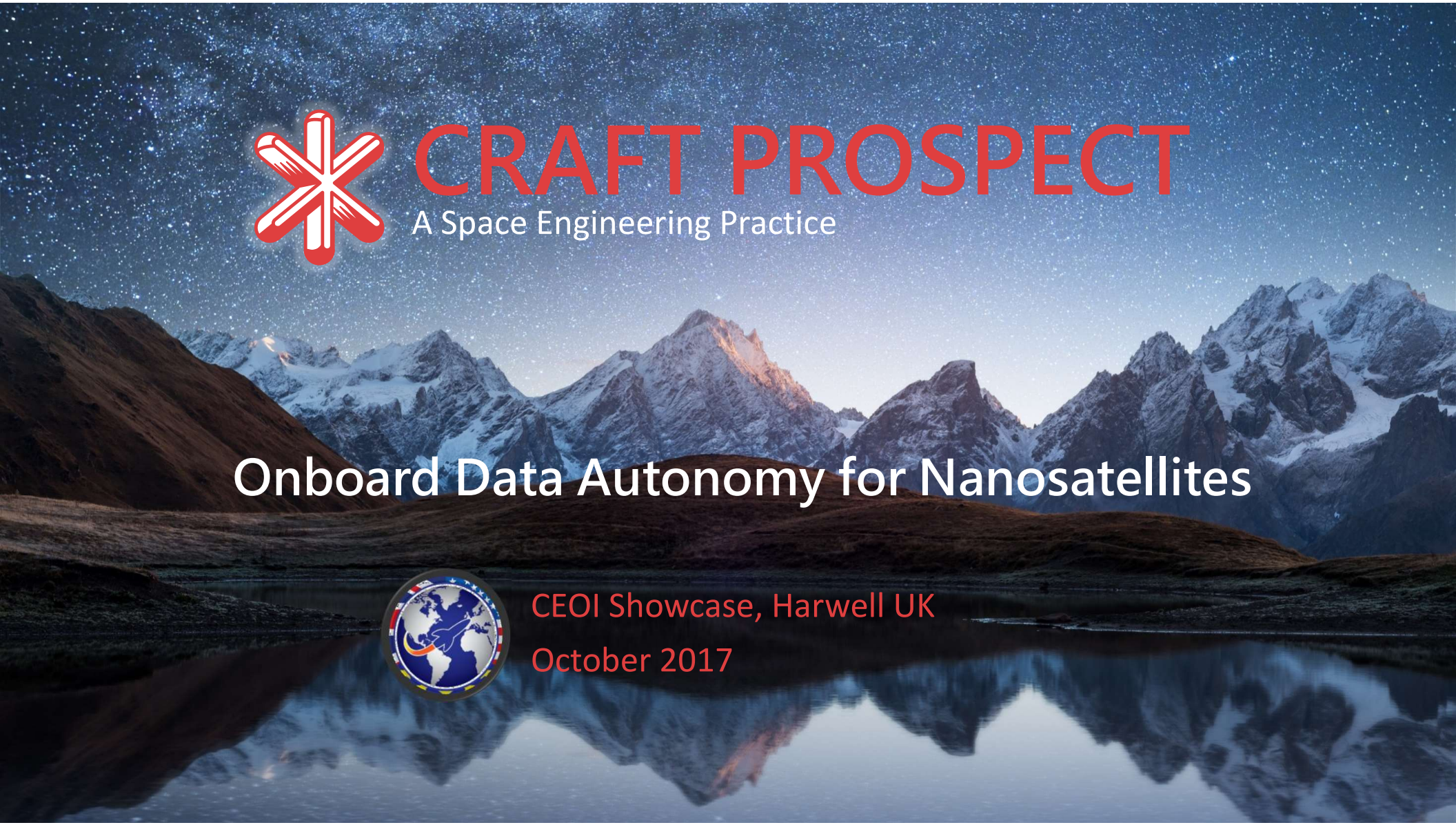
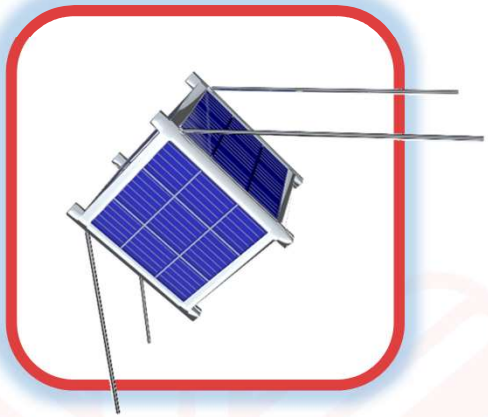
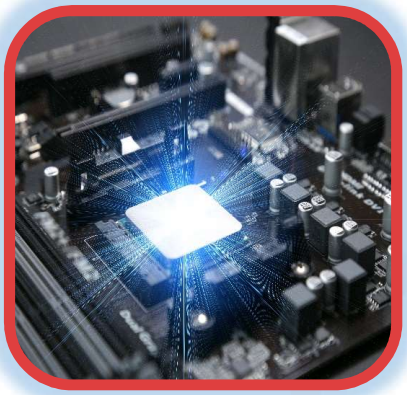

CRAFT PROSPECT
A Space Engineering Practice
Onboard Data Autonomy for Nanosatellites
CEOI Showcase, Harwell UK
October 2017

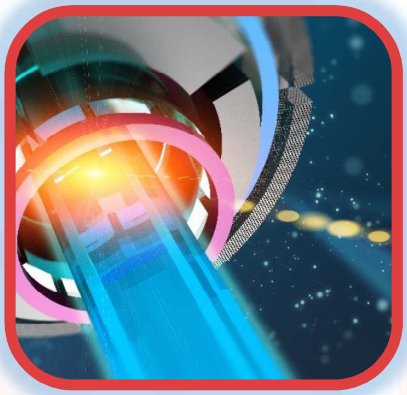
Who we are



NewSpace mission & systems engineering



Collaborative R&D on enabling technology



Novel downstream space applications

Aims & objectives

Unlock potential of Earth-observing nanosatellites for onboard data autonomy to deliver a higher mission return

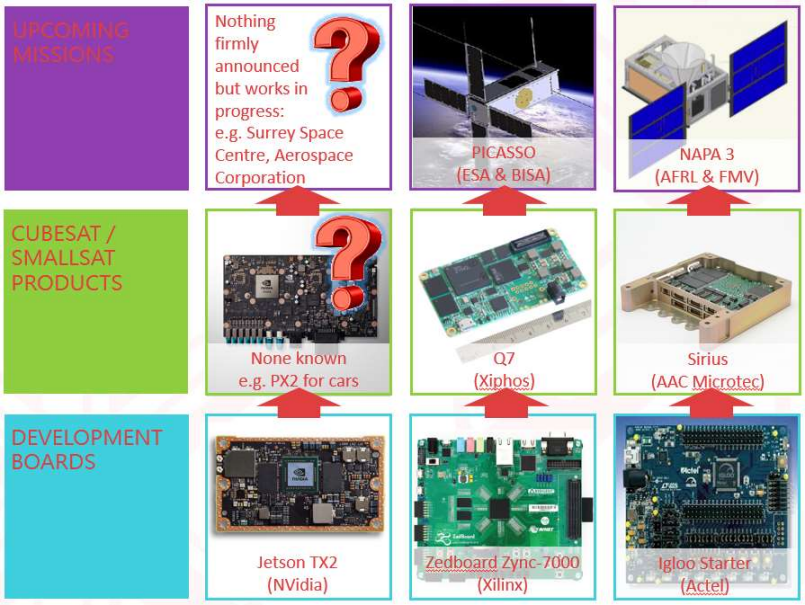
Use cases

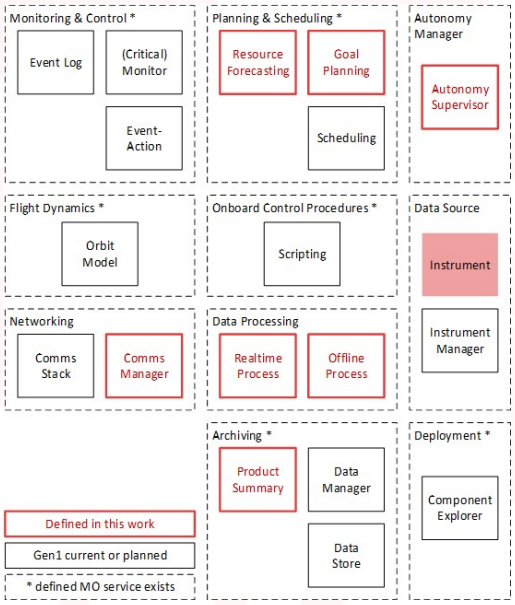
1. Onboard data processing to deliver **actionable knowledge** to a user in-the-field in near-real time for a specific application
2. **Responsive retasking** of remote sensing nanosatellites based on data acquired within the constellation
3. Providing a **contextual summaries** of the information within images stored onboard a nanosatellite
4. Removing features from an image to **minimise product size** in response to a request for specific information content
5. Detecting and potentially modifying the pre-processing at the sensor readout to **correct for anomalies** in the data set as captured

Study approach

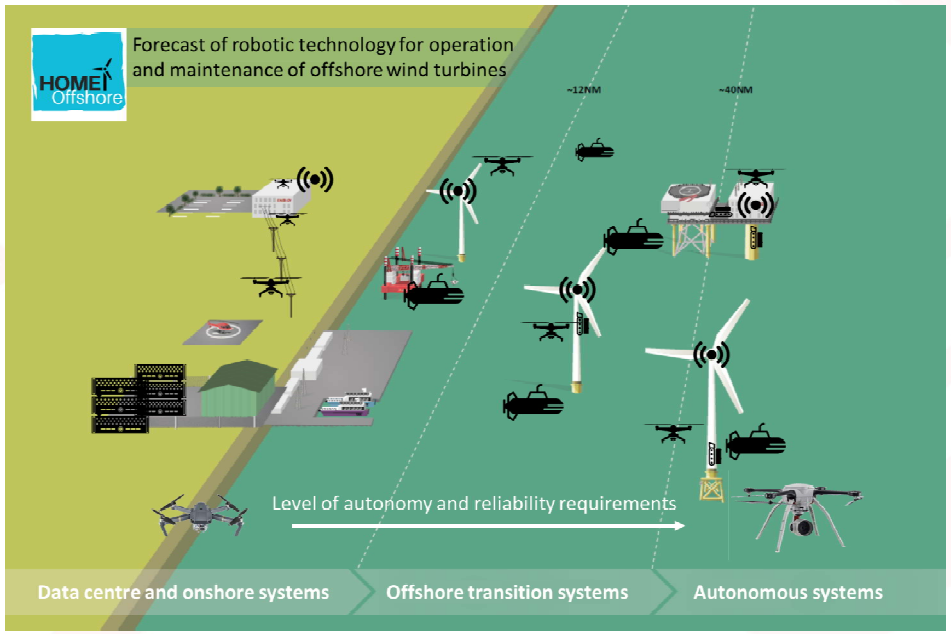
1. Requirements capture and framework definition
2. Baseline application and algorithm survey
3. Prototyping into representative flight hardware
4. Look towards flight opportunities

Framework study





Application baseline



- Near-real time responses required
- Retasking of other vehicles in proximity
- Identification of anomalies, e.g. shipping

- Integration of satellite data within networked system of systems for remote maintenance of large scale offshore wind turbines

Autonomy architecture

Omnivision
OV5642 5MP

DATA SOURCE

HORIZON SCANNING

NETWORKING

FLIGHT DYNAMICS

GOALS

TARGET PLANNER

ORBIT MODEL

RESOURCE FORECAST

RESPONSE

DATA STORE & MGMT

FEATURE CLASSIFICATION

OBSERVATION SUMMARY

ARCHIVING

OTHER PLATFORM FUNCTIONS

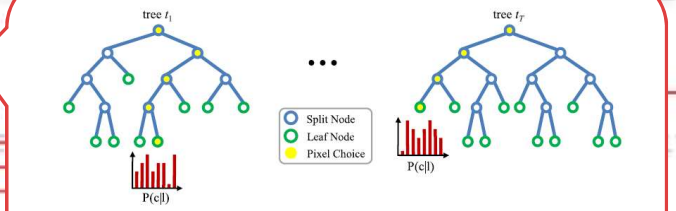
BASELINE SYSTEM

POSTPROCESS CONTROL

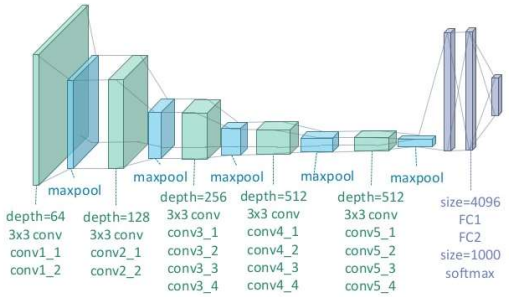
ONBOARD CONTROL PROCEDURES

AUTONOMY SUPERVISOR

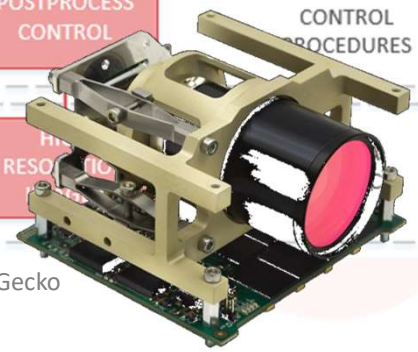
HRI MANAGER



Random forest (Shotton)



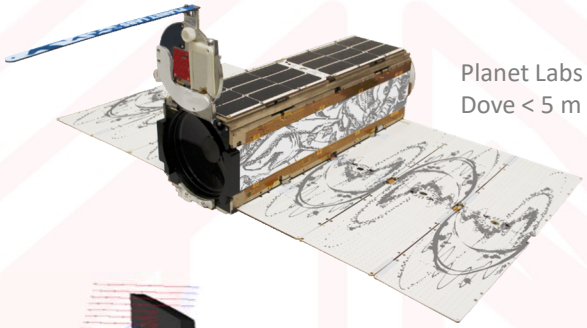
Transfer learning convolutional neural network (VGG18)



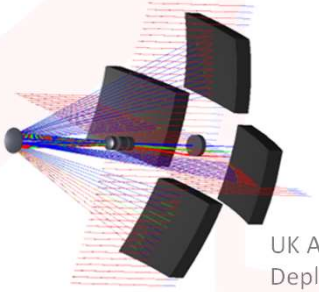
SCS Gecko

Data classification

- Classification of features within high resolution images captured, based on near-Nadir pointing imager
- 1-5 m high resolution imager
- 2-10 km swath
- < 1 min refocus time from slew
- < 5 min from capture to classification response
- Online and offline function



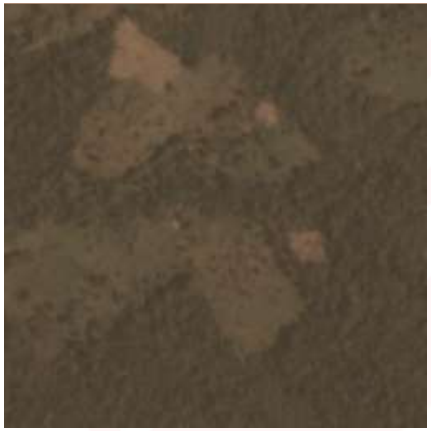
Planet Labs
Dove < 5 m



UK ATC
Deployable Optics Concept

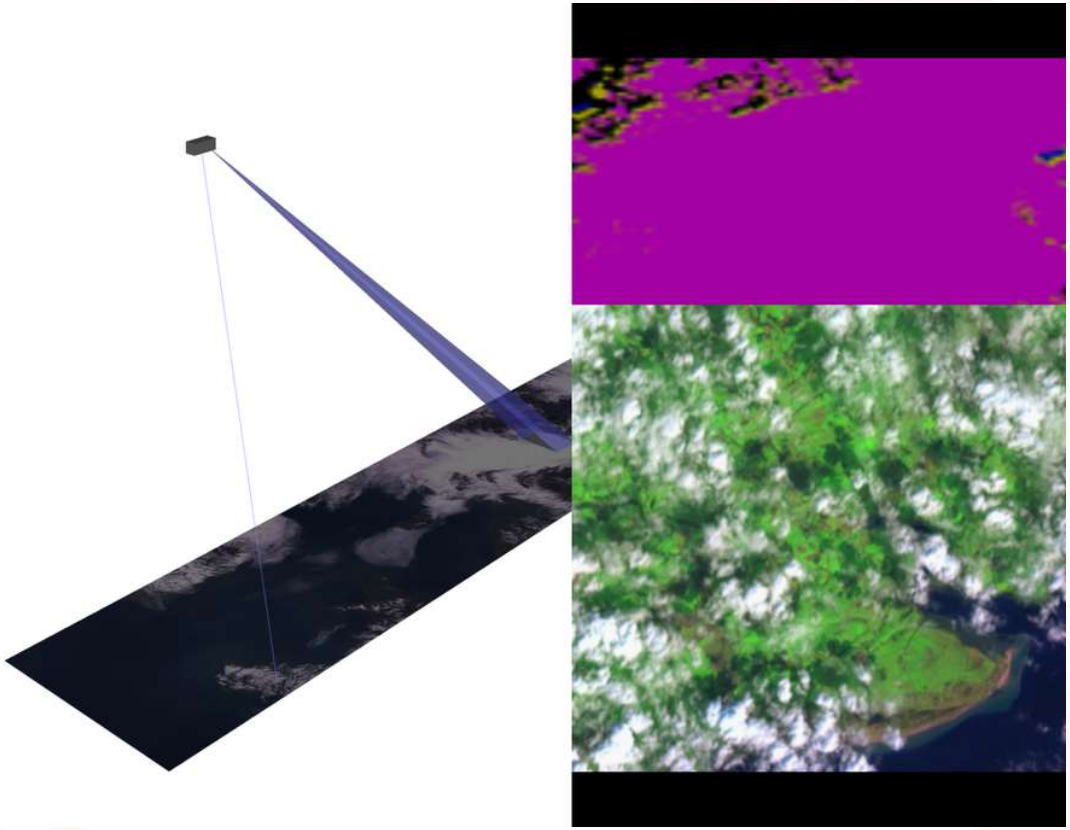
Deep learning

- Applied transfer learning to existing CNN
- Modified neural net
- Trained using Planet Labs classification tiles
- < 1 hr training
- < 1 s inference



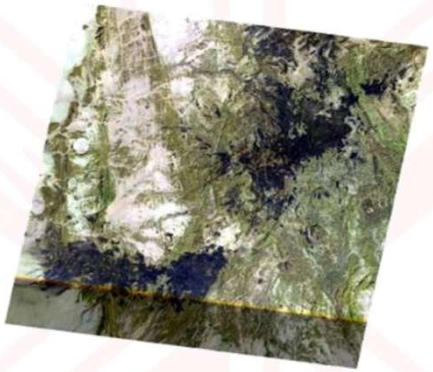
{ ‘agriculture’, ‘cultivation’, ‘habitation’, ‘partly_cloudy’, ‘primary’ }

System modelling

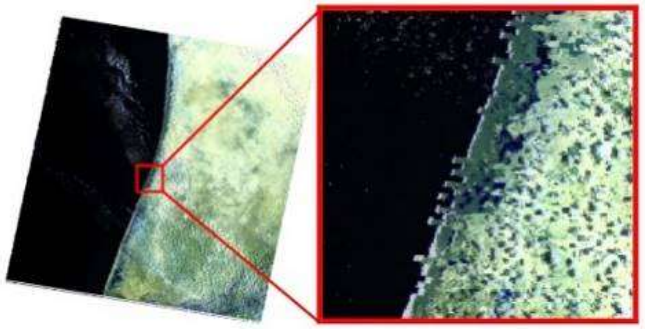


Anomaly responses

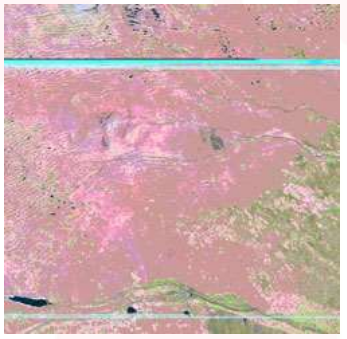
- Initially within the deep learning classifier, to be confirmed through generation of anomalous training data and testing
- Surveyed and classified range of erroneous outputs imagers seen in-orbit resulting from detector, readout, storage, errors



Gain Correction



Pixel Alignment



Sun Glint

Conclusions

- A framework for onboard data autonomy in nanosatellites has been defined for OTS CubeSat systems and current and emerging standards
- The framework has been applied to a particular use case and baseline, allowing enabling algorithms to be identified
- Initial algorithm development, modelling and onboarding effort has provided positive insight into performance to meet requirements
- Work will continue to develop an end to end model and prototype implementation of the baseline space system
- Team would be happy to collaborate with any CubeSat systems, algorithm or instrument developers for demonstration

CubeSats for OnBoard Realisation of Autonomy (**COBRA**) Mission proposed

Acknowledgements

- This work has been part-funded under a Centre for Earth Observation & Instrumentation Pathfinder award on behalf of UK Space Agency, RP10G0435B04
- Team wish to thank Adam Taylor of Adiuvo Engineering for insight into Zynq FPGAs and Xilinx toolchains, and the end user group for contributing ideas, requirements and training data

- Key references, tools and sources used in this work include: Planet Labs classified data sets, USGS LandSat images, and open source releases of TextureCam, Fmask, and AlexNet

Centre for
EO Instrumentation

Questions?

Thanks

E steve.greenland@craftprospect.com

W www.craftprospect.com

@ @strickengremlin