High speed 3D capture for Configuration Management
DOE SBIR Phase II

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Nuclear power plant configuration management requires a new solution

- **Modern configuration management requires as-built information**
  - **Accurate, up-to-date**
  - **Cost-effective**

Nuclear facilities have high density of components & tight tolerances

Existing solutions are too costly & slow.

- **Existing approaches (3D laser scanners) require extensive setups and post-processing**
  - **1000s of scans per facility**
  - **Manual registration to plant coordinate system**
  - **Separate imagery for component ID**

- **New tablet scanners are limited**
  - **Short range operation, indoor only**
  - **Slow acquisition**
  - **Poor resolution**
  - **But less expensive ($5 – 10K + software)**

**TetraVue's 3D camera technology promises automate registration without setups
- Imagery & coordinate information from a single sensor**

Megapixels, 30 m range, low power

Phase II objectives are to demonstrate practicality of high resolution 3D video for cost-effective configuration management

- 1" accuracy to plant system [ultimate goal is 2-4X better for critical dimensions]
- Eye-safe (class 1M)   Class 1
- Max Range 20 – 30 m
- Near real-time 3D models of complex structures
- 10 - 40°C operation
- Demonstrate 1 person operation/handling

- **Improve hardware**
  - **Improve camera performance by 3X over Phase I**
    - **Make eye-safe & portable**

  - **Build handheld, single person operation 3D camera prototype**

- **Improve registration**
  - **Show near-real-time, _accurate_ model generation**

> **End-to-end demonstration: incorporate 3D model into common CM software in < 4X the capture time**
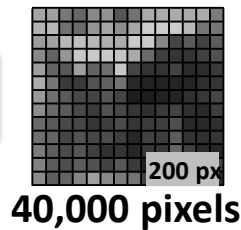
Optical time-of-flight (oTOF) makes megapixel 3D imaging a reality

TRADITIONAL
Electronic TOF

Lens   Detector

x N

and many others...
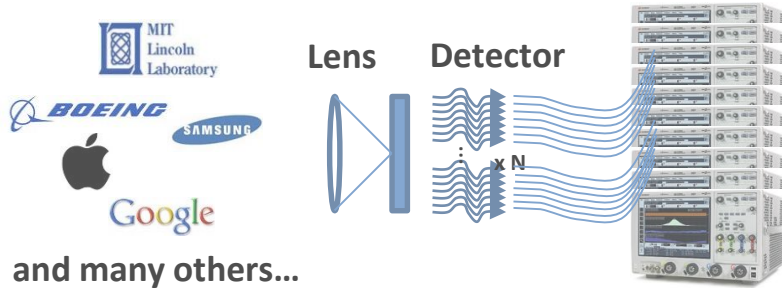
2M GHz oscilloscopes

~10 – 40 kpx

200 px

40,000 pixels

Think different

NEW APPROACH

Optical TOF

Lens CMOS

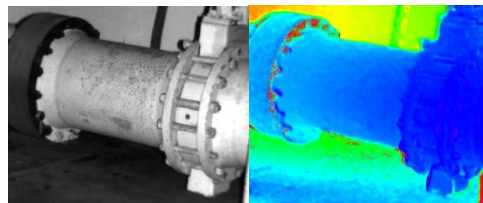x N
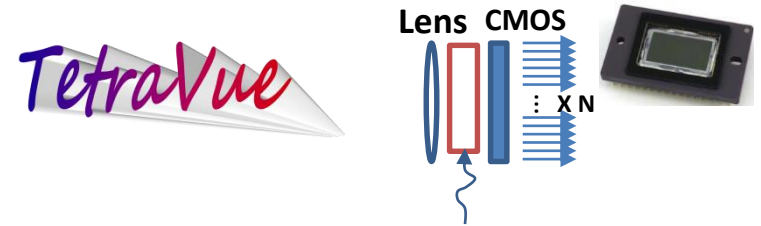
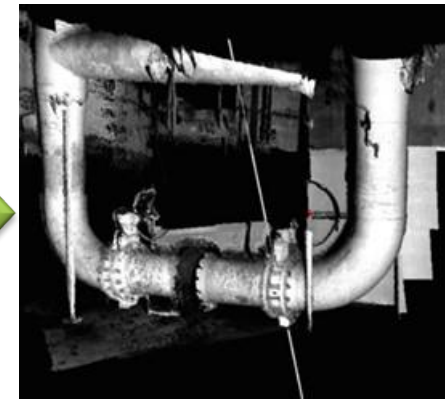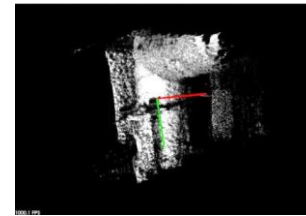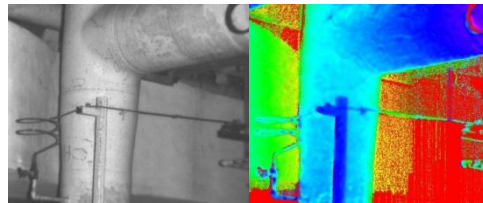**1 optical system + 1 CMOS sensor**

2Mpx

1080 px

1M pixels
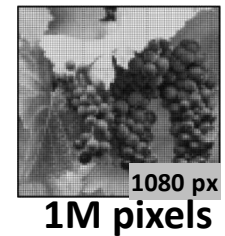
High resolution 3D video can be registered to create high resolution 3D point clouds and models of complex areas

Simultaneous Intensity & range maps at 10 fps

Generation of 3D object frames
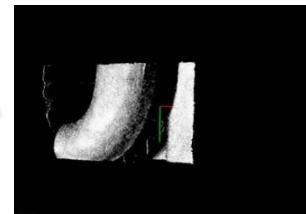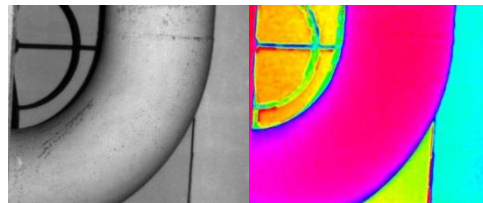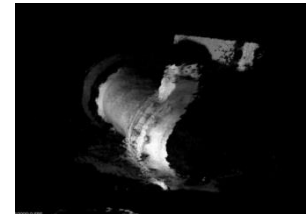
TetraVue Prototype 3D camera at site

Final 3D model

3D CAMERA PROTOTYPE

Handheld

Camcorder-like operation

Phase II improved 3D capture hardware

NSF/ Phase I

Phase II

Electronics backpack

Handheld camcorder

α prototype

|	Old prototype	Phase II prototype	α prototype
Increased FOV	14° x 11°	24° x 12°	39° x 22°
Eyesafety	Class 4	Class 1	Class 1
Emission	Visible	IR	IR
Weight	60 lb	10 lb/25 lb	12 lb/12 lb
Operability	2 people	1 person, battery	remote

TetraVue

Phase II 3D camera is complete

- **Portable 3D camera**
  - **Handheld: 10 lb**
    - **Optics & light slicer meet spec**
    - **Integrated diode illuminator**
  - **Backpack: 25 lb**
    - **Computer & battery**
    - **Power & timing electronics**

- **Operation**
  - **Complete UI on handheld unit**
    - **Motorized focus**
    - **Record on/off**
    - **Status**
    - **Range or Image viewing live**
  - **Some noise reduction**
  - **Data pipeline on GPU**
    - **Will be transitioned to FPGA**
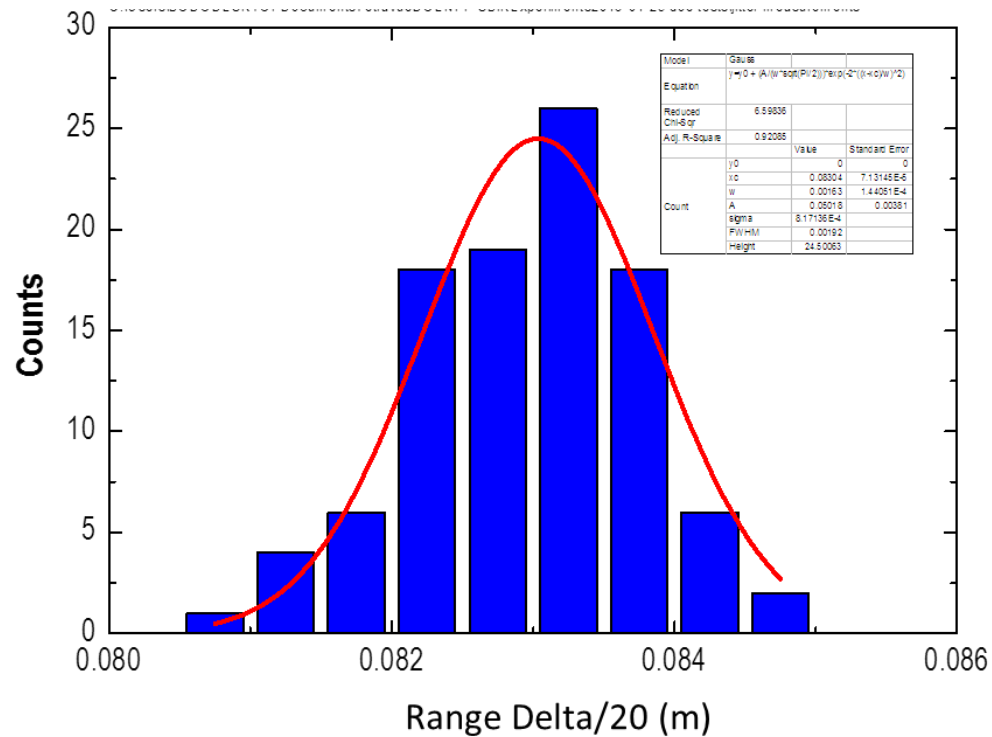

range

intensity
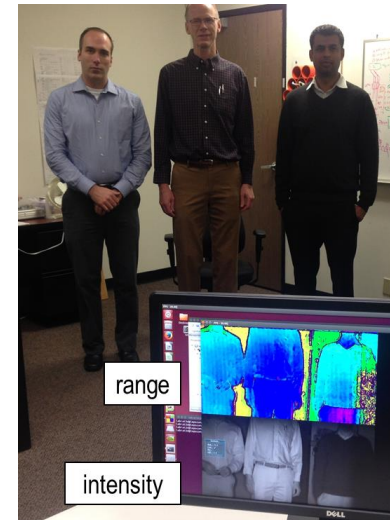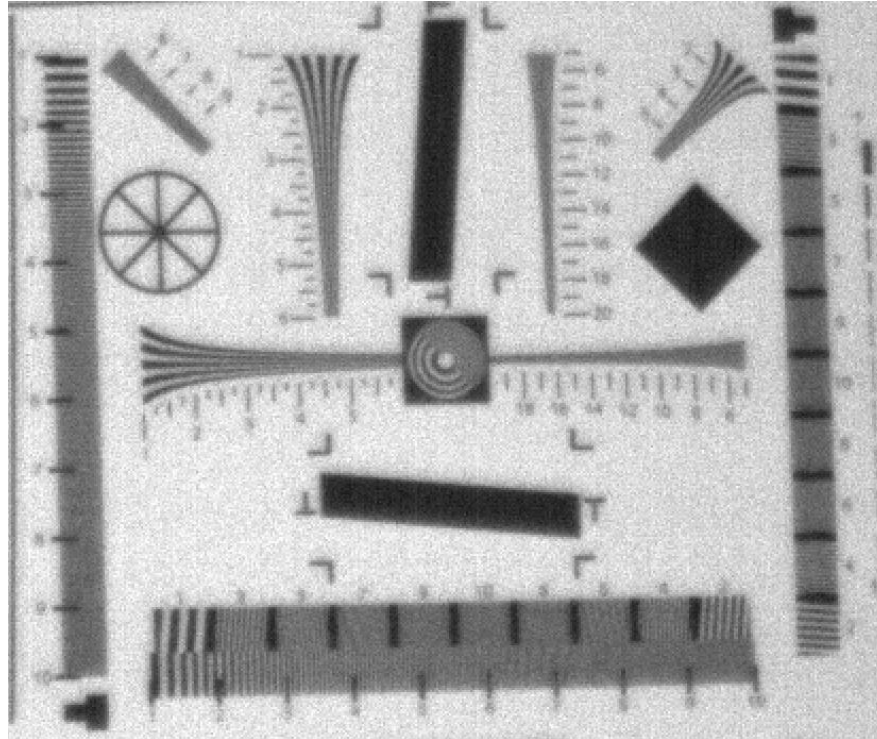
Main focus was to miniaturize optics
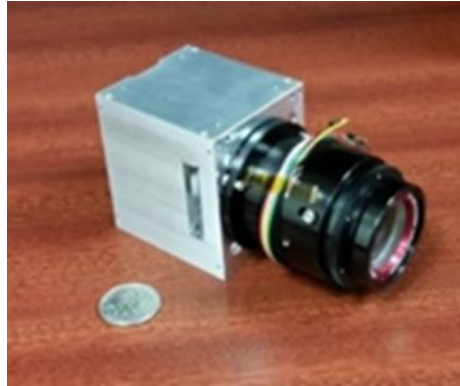
- **Custom optical designs and components**
- **Improved alignment and assembly**

Range jitter is < 2 cm RMS

- **We have identified modification to electronics to reduce jitter by 50% (< 1 cm)**
  - **Implemented in α Prototype**
- **Can further correct to < 4 mm in post-processing**

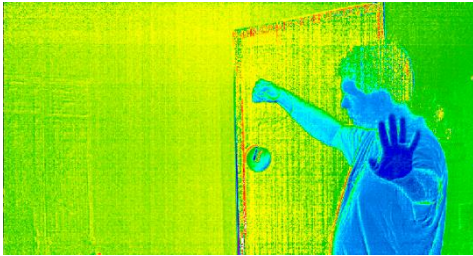# IR lens meets optical performance requirements

- **IR sensors cause some degradation in optical accuity**

Digital Pipeline has been improved and is low latency on a low-end GPU

TetraVue camera data

Intensity image

Range image

- **Fully implemented, GPU based**
- **Current performance specification**
  - **Real-time**
  - **30 fps**
  - **250 ms total data latency (to range map)**
- **Also implemented**
  - **Basic filter options**
  - **Rudimentary GUI**
  - **3D rendered view (at reduced FPS)**
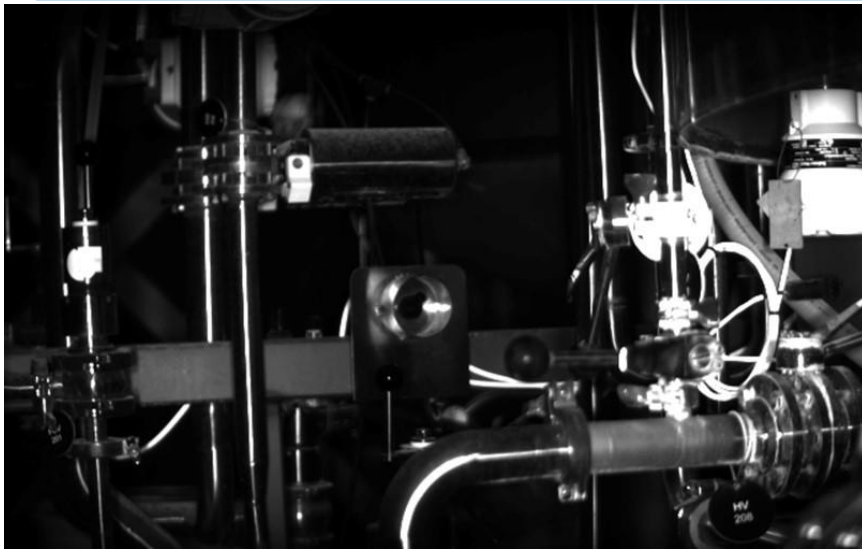
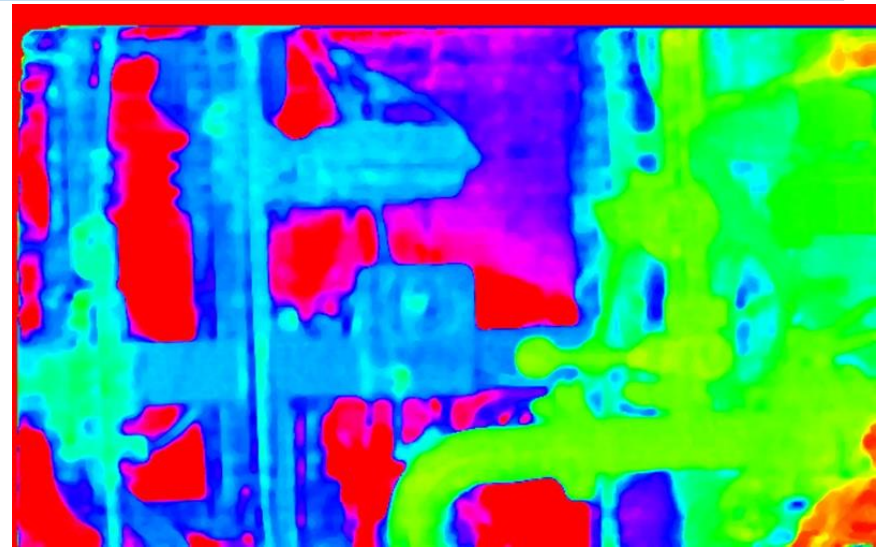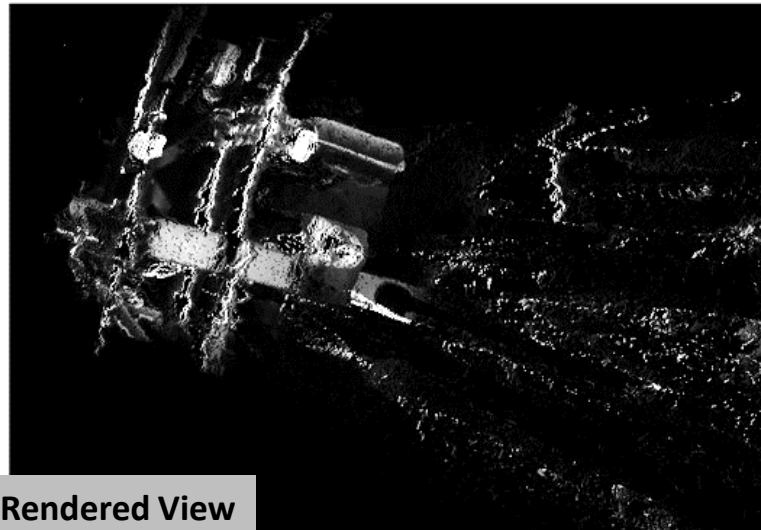# 3D camera produces high res image + range map live
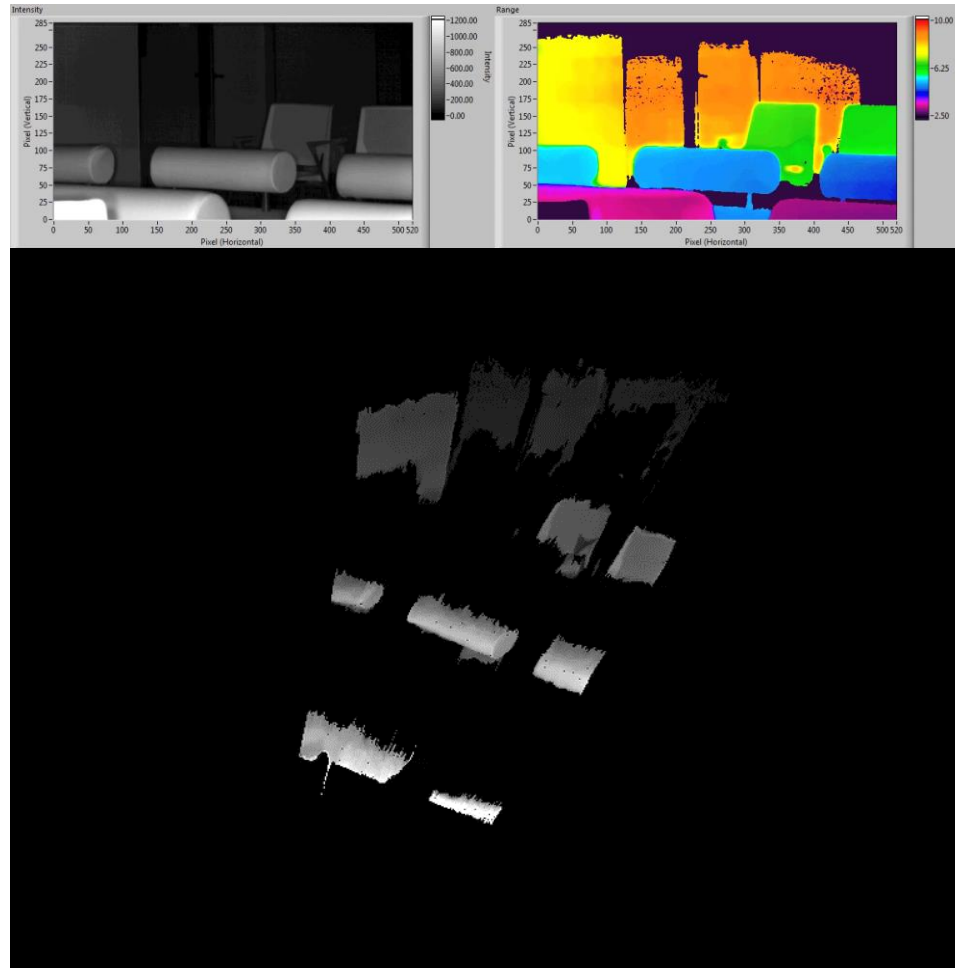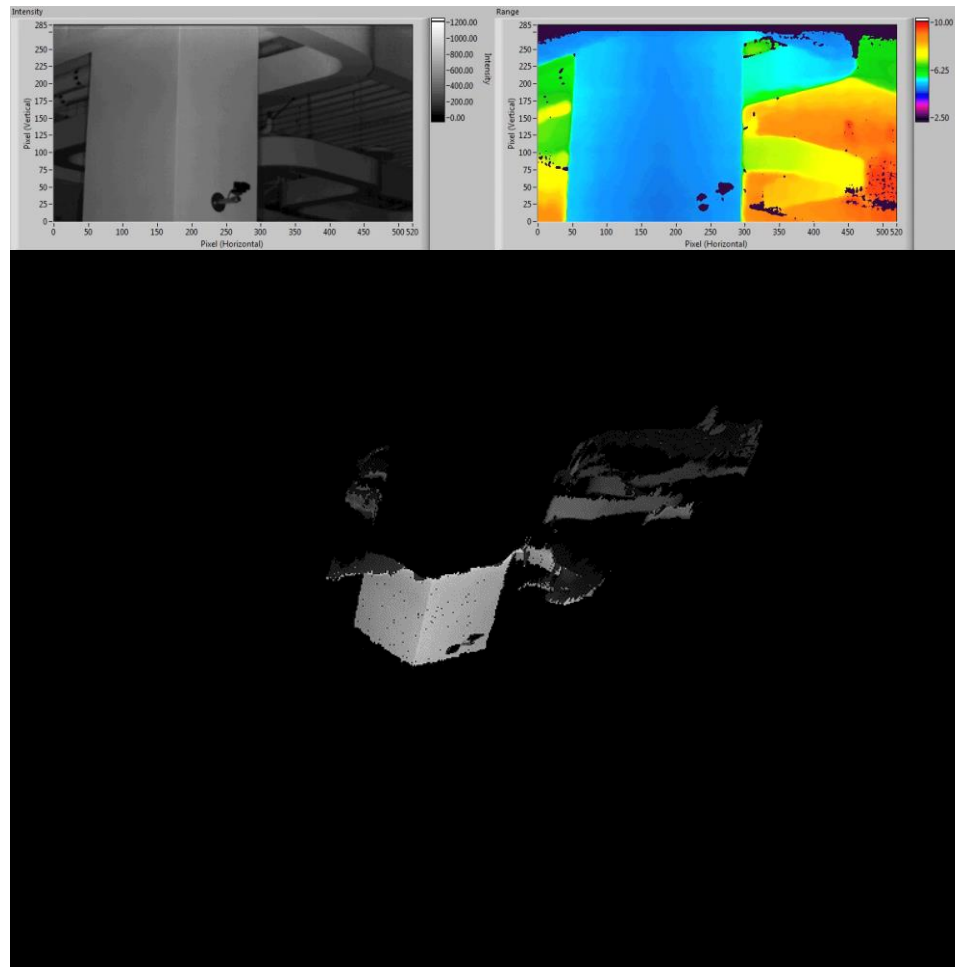

Image Map

Range Map

Rendered View

INTERIM TEST DATA

TetraVue

Complex scenes can be recorded
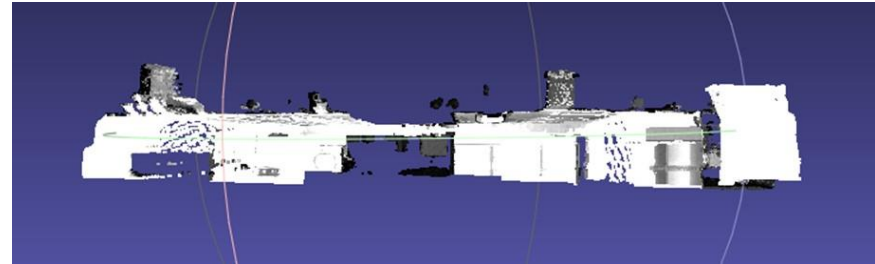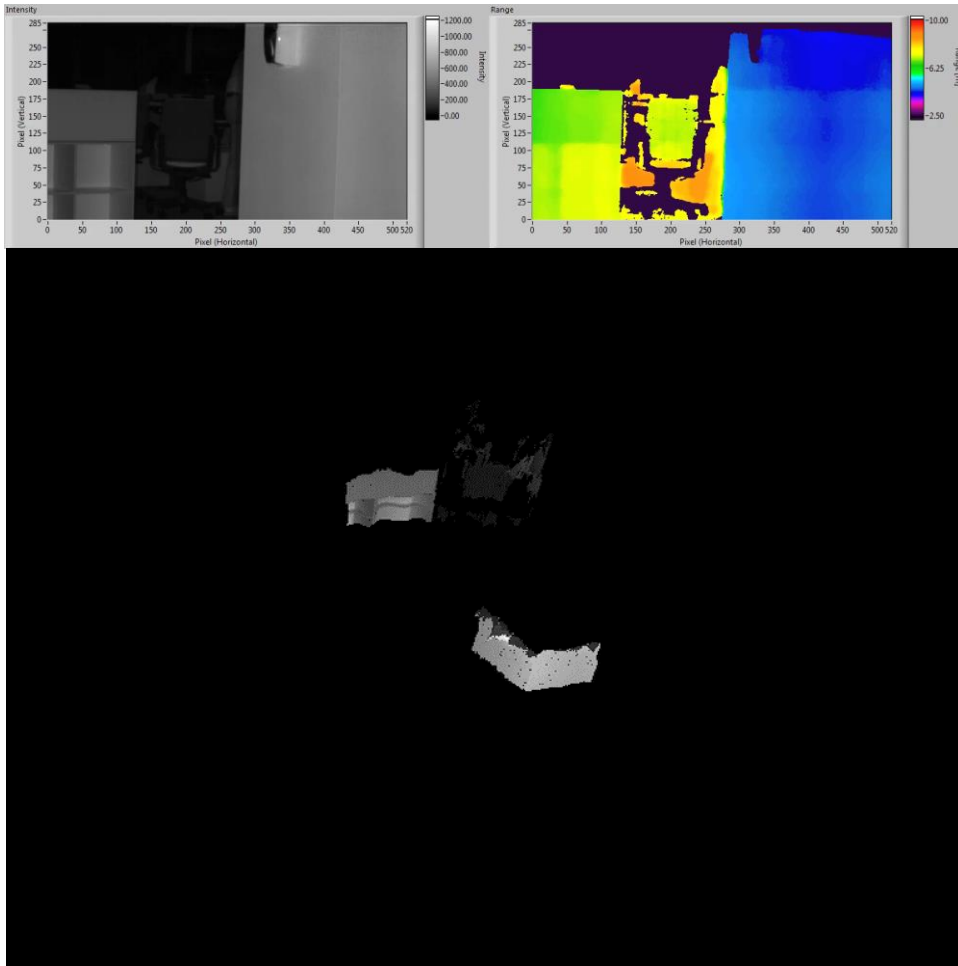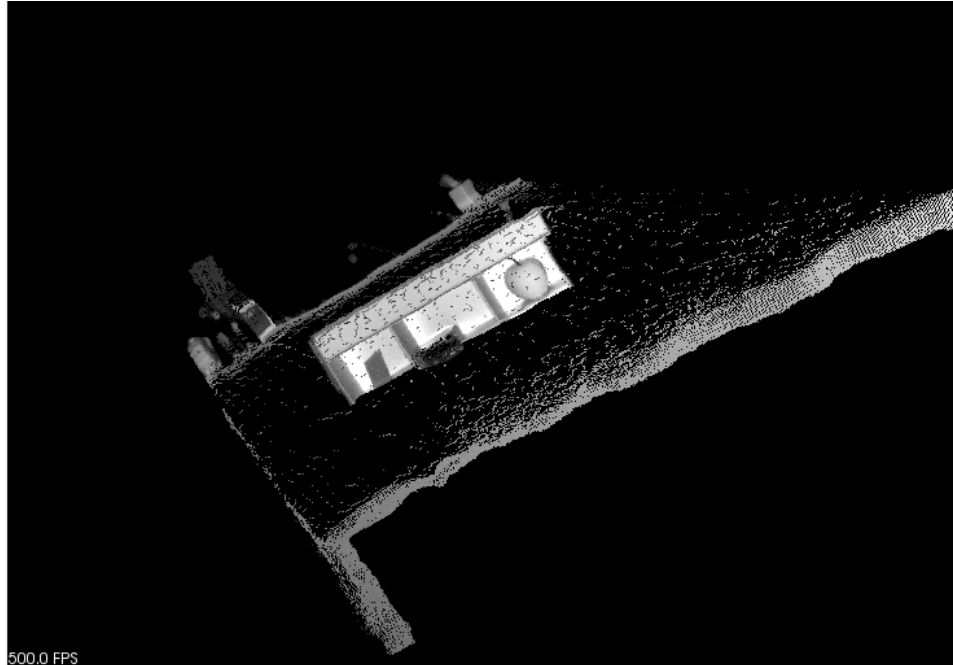
Camera pans along structures

Video stitched into a single point cloud

Rendered view

500.0 FPS
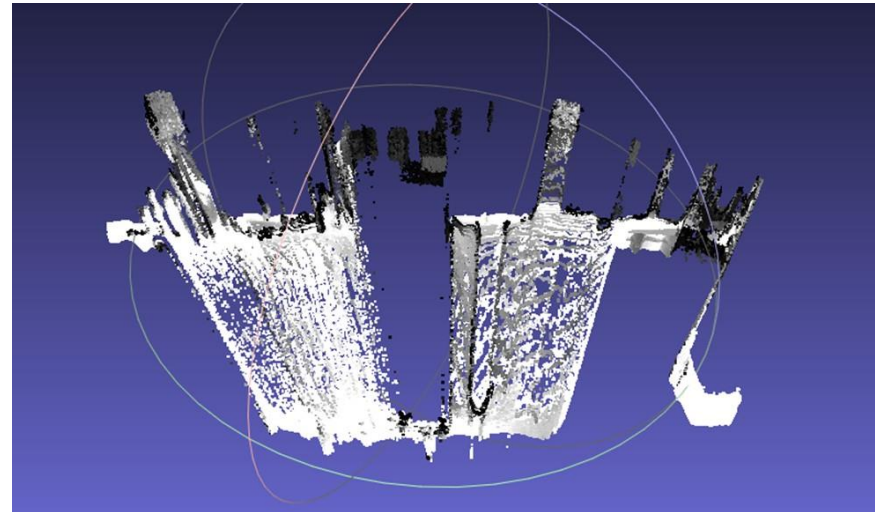
Moving objects and structures can be tracked
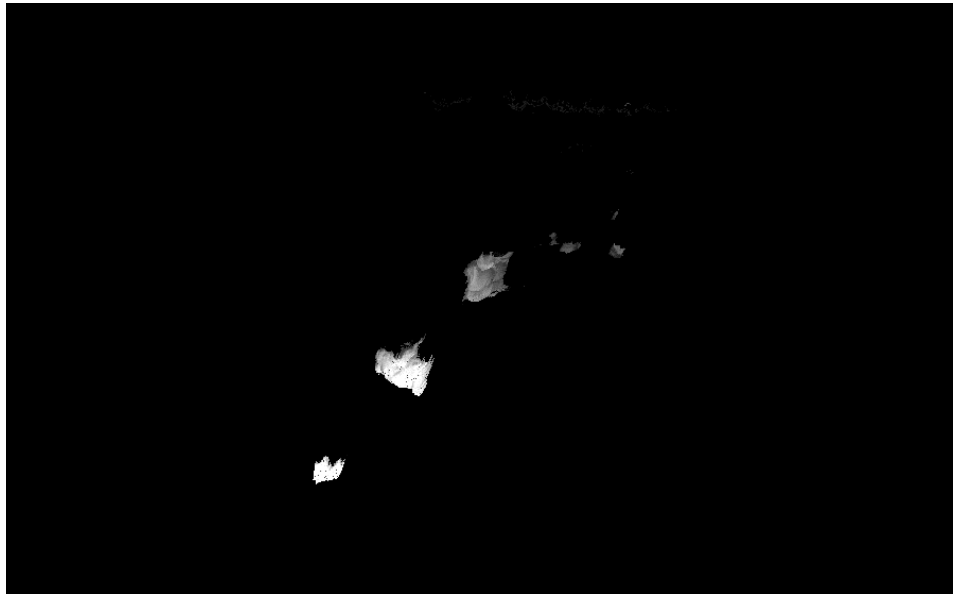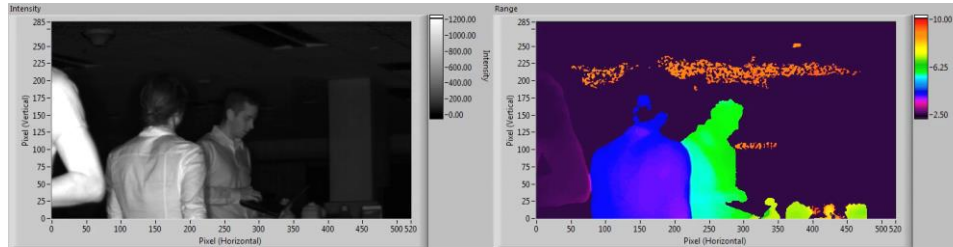
REGISTRATION

TetraVue 3D registration solution approach combines multiple data to improve robustness

- **Desire to improve state-of-the-art by in accuracy, drift, and robustness**
  - **Up to 10X**

- **Current algorithms focus on 1 aspect of available data**
  - **Imagery or depth**

- **TetraVue intends to combine several**
  - **Reduce drift**
  - **Improve robustness**
  - **Improve overall resolution & accuracy**

Enhanced Registration Algorithm

Depth stream

Image stream

Low cost IMU

High resolution Long Range Multi-look

Voxel-based 3D Model
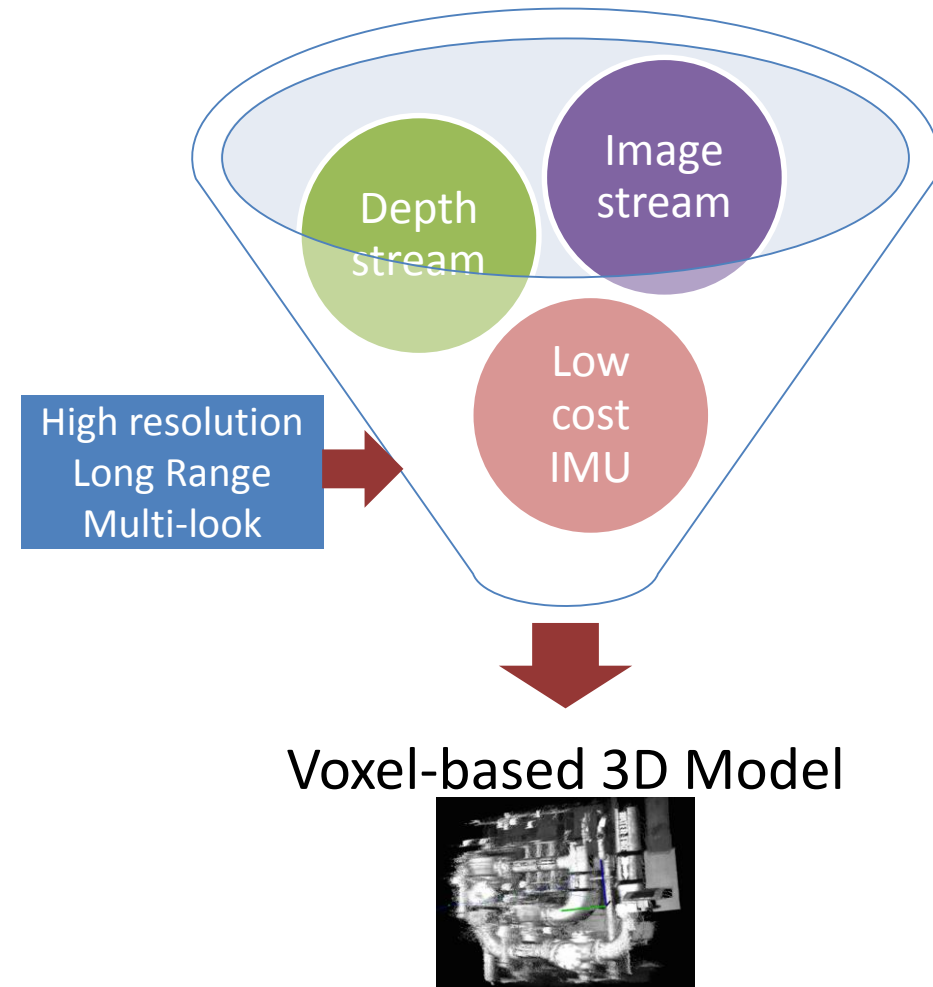
Working with CSA to automate data import into Panomap CM software

- **Can automatically register TetraVue point cloud to existing database/structures**
  - *Integrate data into plant coordinate system*

- **Provides for difference calculations between multiple scan or data sources**

- **Objective is to reduce time to access data for decision-makers**
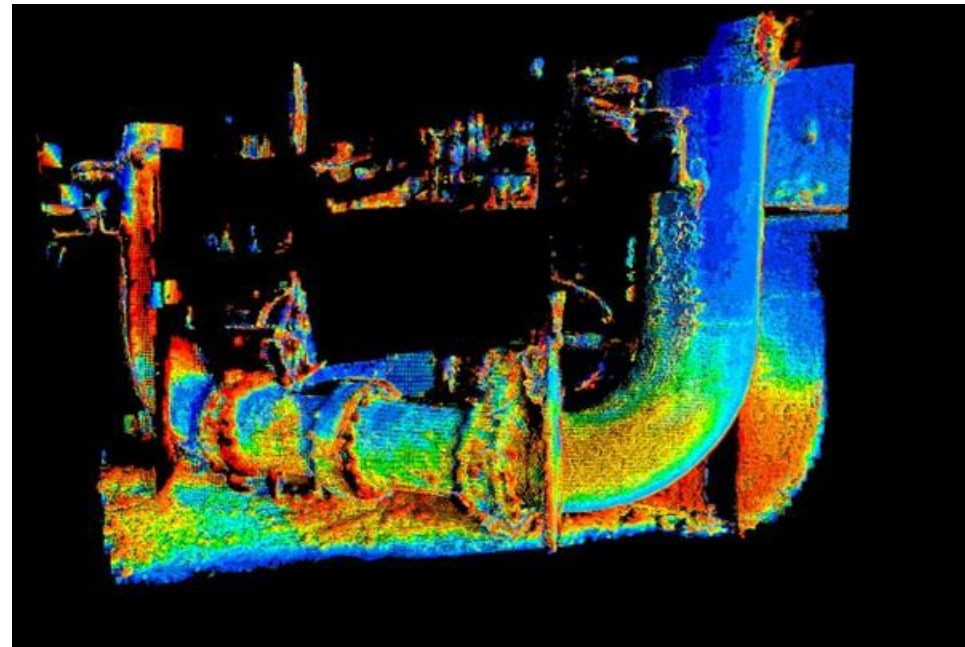
What is left?

- **Hardware**
  - **Testing and optimizing camera for more robust operation**
    - **Temperature changes**
    - **Dark surfaces**

- **Registration**
  - **Complete registration pipeline**
  - **Continue to work with potential COTS solutions**
  - **Complete testing of CM integration**

- **On-site demonstration**

Future

- **CM and point clouds are just part of general push towards virtualization of asset management**
  - *Includes BIM and other initiatives*

DAQRI Augmented Reality

- **Data acquisition is an oft-forgotten key**
  - *Must be robust, detailed, and cost-effective*

Magic Leap Augmented Reality

- **TetraVue has completed raising capital to productize its technology**