Cygnus - Expanding Capabilities while Maintaining Reliable Scheduled Deliveries

GLOBAL PRODUCT DATA
INTEROPERABILITY
SUMMIT
2020

Webinars

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Quick Bio

- **Virginia Tech**
  - **BS Aerospace Engineering**
  - **Focus in aircraft controls**

- **George Washington University**
  - **MS Systems Engineering**

- **Started working at Orbital Sciences in 2006**
  - **Tested avionics and power components**
  - **Orbital → Orbital ATK → Northrop Grumman**

- **Working on the Cygnus product line from 2008 – 2020**
  - **Guidance Systems**
  - **Systems Engineer**
  - **Chief Engineer**

Fortunate enough to be involved with:
- **Spacecraft Design**
- **Software Design**
- **Integration & Test**
- **Launch Campaigns**
- **Mission Operations**
- **Customer Interface**

- **What is Cygnus?**

- **Development Operations (DevOps)**

- **Merging DevOps onto a Spacecraft Product Line**

What is Cygnus?

Cygnus is a product line spacecraft manufactured and operated by Northrop Grumman Space Systems

Developed under the Commercial Orbital Transportation Services (COTS)

The spacecraft now makes routine cargo logistics missions for the International Space Station (ISS) as part of the Commercial Resupply Services (CRS) contract to the International Space Station (ISS)
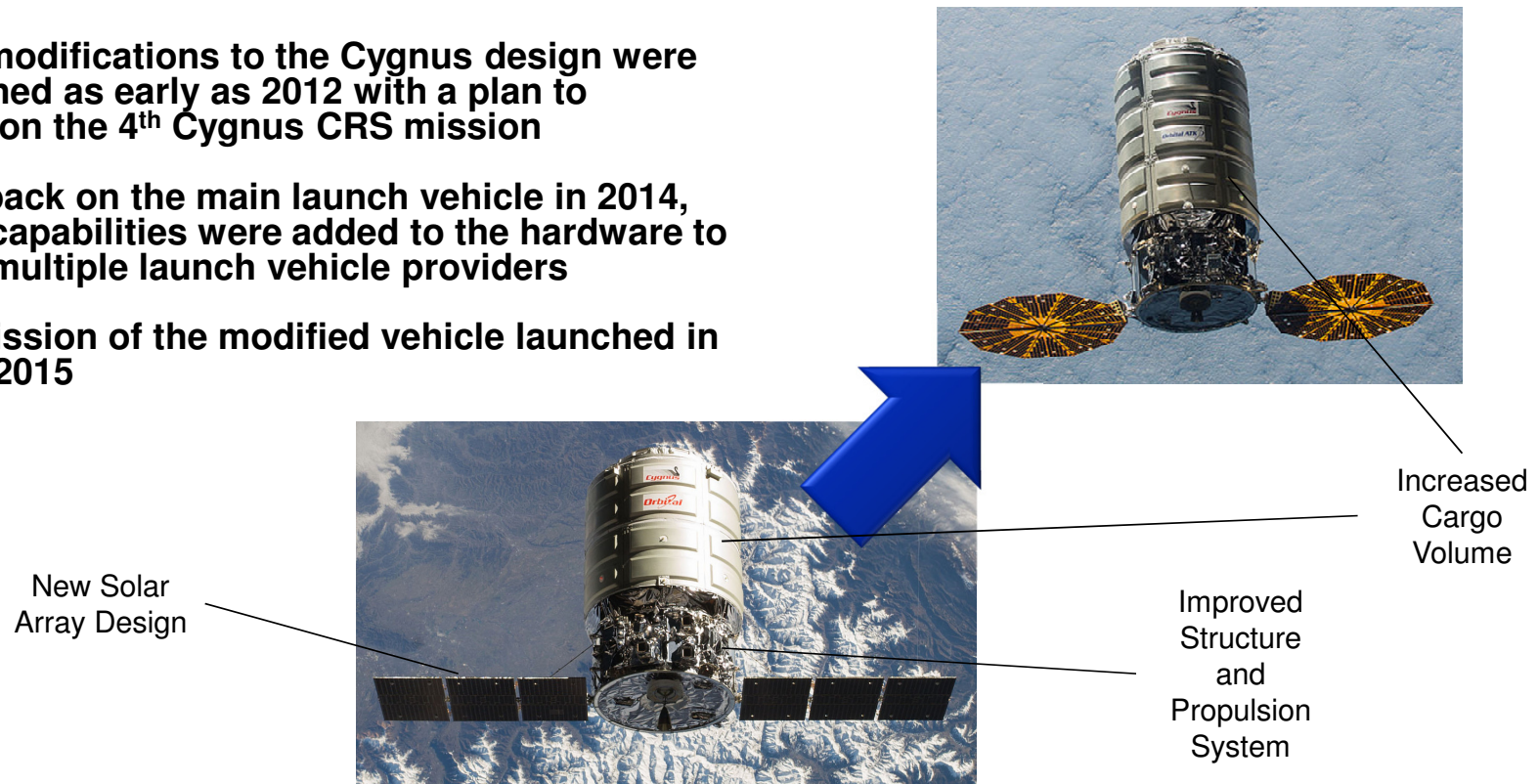
Cygnus History 2008 - 2013

- **Development of the Cygnus spacecraft started in the Fall of 2007 as NASA announced they were awarding the COTS contract to develop a commercial cargo provider to the ISS**

- **Orbital Sciences was selected in February 2008 and design work began in earnest for both a launch and space element, with the space element leveraging heavily on existing architecture designs for both LEO and GEO spacecraft**

- **By the end of 2008, the Cygnus design had progressed far enough to get a NASA award from the Commercial Resupply Services program for multiple missions; thus establishing the Cygnus spacecraft as a product line with multiple vehicles**

- **The Cygnus spacecraft completed its Critical Design Review in 2010 and began manufacturing and assembly**

- **In September 2013 Cygnus completed its maiden flight**

Cygnus History 2013 - 2016

- **Hardware modifications to the Cygnus design were being planned as early as 2012 with a plan to implement on the 4th Cygnus CRS mission**

- **Due to setback on the main launch vehicle in 2014, additional capabilities were added to the hardware to launch on multiple launch vehicle providers**

- **The first mission of the modified vehicle launched in December 2015**

Increased Cargo Volume

New Solar Array Design

Improved Structure and Propulsion System

- In April 2014, NASA announced new requirements for the delivery and disposal of pressurized and unpressurized cargo to and from the International Space Station under CRS-2

- Cygnus was selected in 2016 to support this contract along with additional hardware modifications which leveraged off of existing design capabilities already demonstrated

- These modifications were critical in supporting additional service capabilities for fast delivery of time sensitive cargo (see next slide)

Increased Thermal Control System Capabilities

Added Addition of Unpressurized Cargo Removal Attachments

Cygnus History 2018 - 2019

Starting with the NG-12 mission we started offering fast delivery of late loaded cargo

Ground to ISS within 96 hours maximum
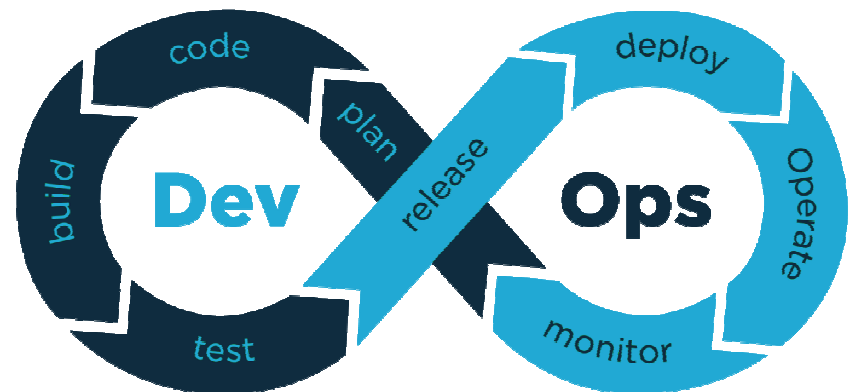
**Demonstrated first on the NG-11 mission**

Development and Operations (DevOps) is a set of practices that is designed to shorten the lifecycle of software development by integrating operations activities with developers to safely deploy and test applications and maintain a common solution

- **From a timeline perspective, DevOps entered the Cygnus engineering world in 2009 with the first State of DevOps report getting launched in 2012**

- **At that time, the program was in the midst of manufacturing for the first generation Cygnus vehicle and was not actively explicitly using DevOps methodology**

- **In retrospect, while not explicitly used on Cygnus, many of the same principles were used within the hardware design and test of the vehicle**
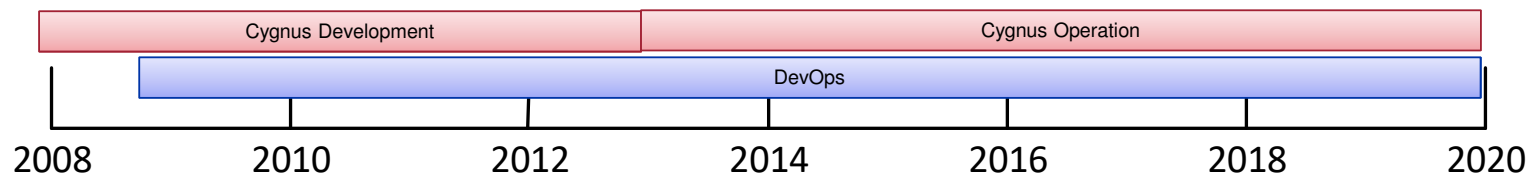
Cygnus Development	Cygnus Operation
DevOps	

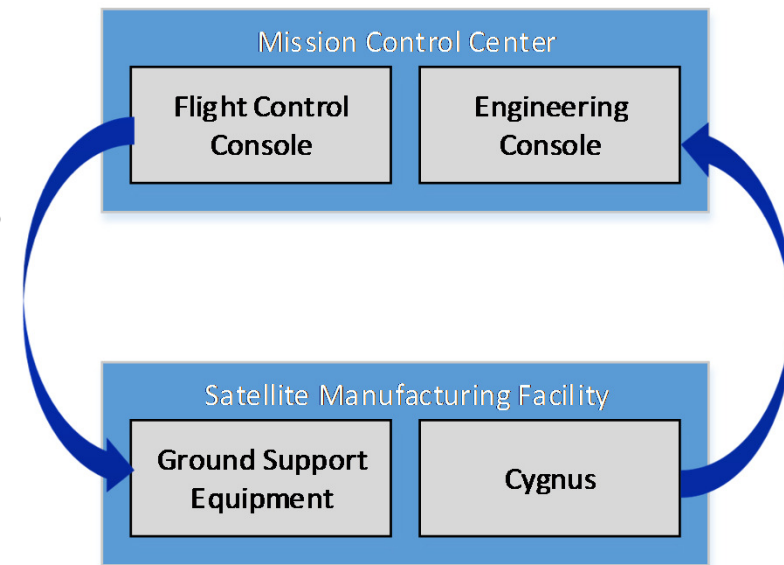2008   2010   2012   2014   2016   2018   2020

- **Cygnus was designed, assembled, tested and operated by Northrop Grumman engineers and flight controllers**

- **By combining engineering and operations under the same umbrella, we were able to integrate flight controllers with system architects early in the design**
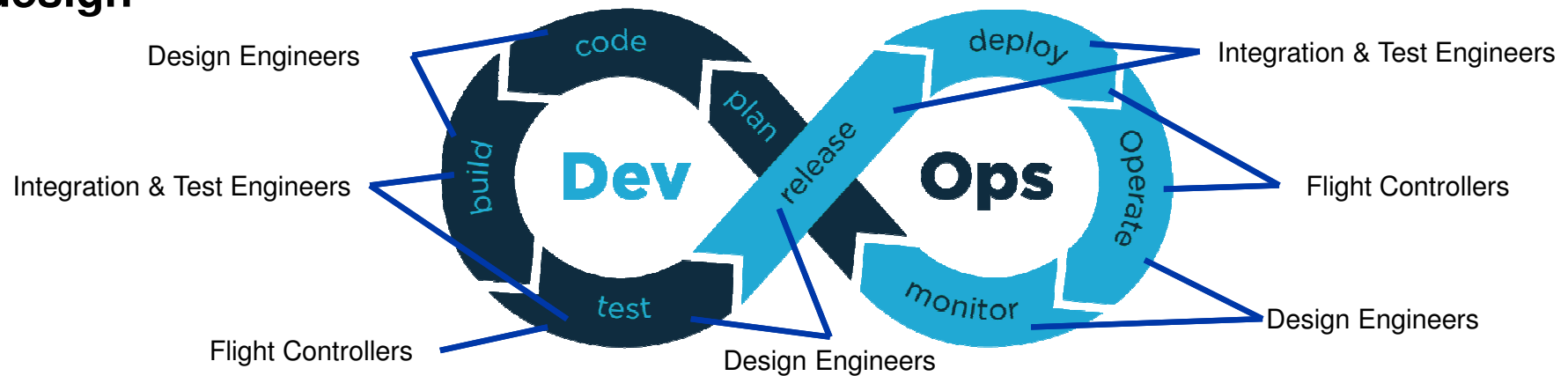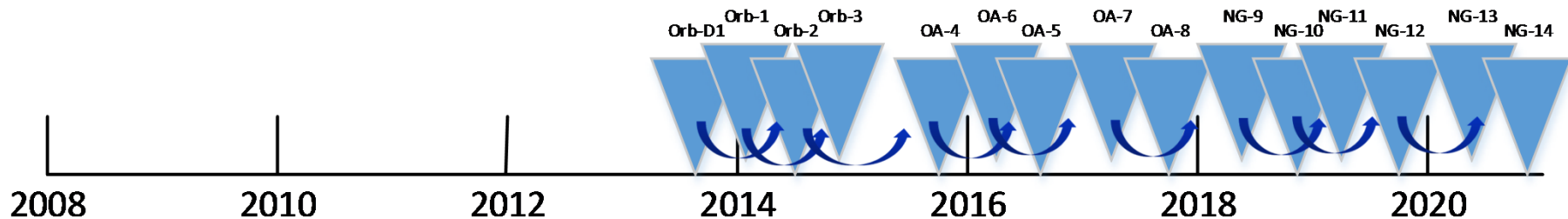
DevOps at a Cygnus System Level

- **To achieve this, significant investments were made to develop high fidelity test platforms which integrated directly with the Control Center**

- **Actual flight procedures were developed on flight-like hardware in conjunction with design engineers for instantaneous feedback**

- **This led to quick identification of system deficiencies which could be fixed through hardware, software or in some case operations**

- **The culmination of this effort resulted in a complete 24 hours test with the flight operations team to replicate the complete mission 1 year prior to the actual flight**

Mission Control Center

| Flight Control Console | Engineering Console |

Satellite Manufacturing Facility

| Ground Support Equipment | Cygnus |

DevOps at a Cygnus System Level

- **Additionally, engineering staff were utilized for operations support to integrate feedback on flight performance directly to the designers**

- **Each mission culminated with flight reports and identification of modification improvements which could be dispositioned at a program level with customer involvement**

- **Even when focusing on a single spacecraft DevOps, general principals can be applied to the hardware to increase the communication**

- **Thorough definition of ICDs with the use of Mass Models and Simulated Loads can shorten the time for verification and also identify areas which need redesign prior to implementing the final flight hardware**

- **3D printing technologies are used to develop rapid prototypes of changes to turn CAD files into physical hardware which can be temporarily installed for fit checks and feedback prior to finalizing drawings**

DevOps at a Cygnus Hardware Level

- **Continuous review of existing hardware and feedback to engineering and design supports DevOps philosophies**

- **Utilizing standard interfaces designed for one component on a brand new component using an adaptor or minor modification to the new component**

- **Early hardware prototyping allows for testing of core functions before final hardware is produced**

DevOps at a Cygnus Process Level

- **All Change Control Boards have a clear manager with an expected attendance list**

- **Attendance expands across engineering and management and uses all disciplines, technicians and inspectors to pull feedback within the CCB**

- **CCB guidelines are clearly established to keep feedback focused on improving key performance metrics**

Applying DevOps to Mechanical Work

| Code | → | Design |
Build	→	Draw
Test	→	Review
Operate	→	Installation
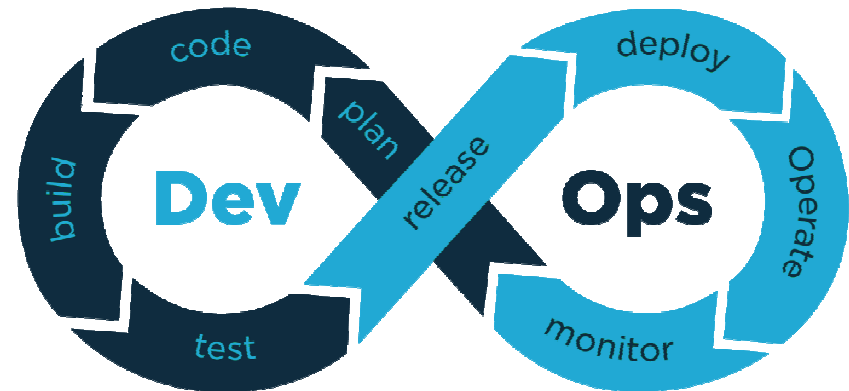
Signs of Success Schedule

- **Schedule performance is the first key measurement of success**

- **OA-4, NG-9 and NG-12 each contained major block modifications which did not have a significant impact on schedule**

- **Cygnus has been able to maintain a steady cadence of mission execution which has increased reliability for on time deliveries**
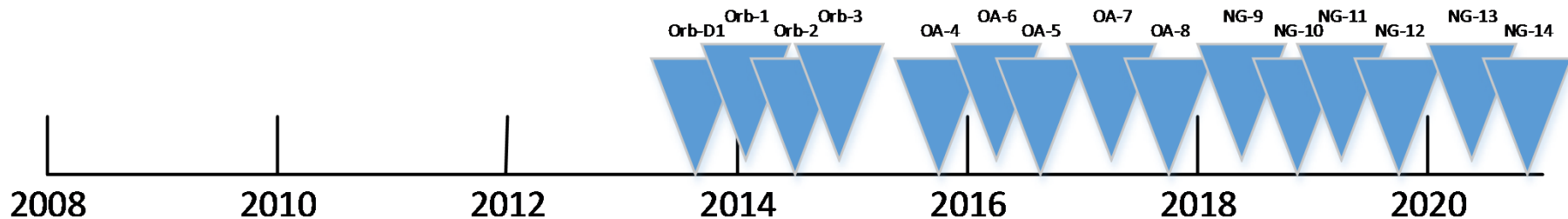
Signs of Success Quality

- **Quality of mission performance is the second key measurement of success**

- **While not every flight operates 100% perfect, no flight observations resulted in a failed mission or damage of any cargo on delivery**
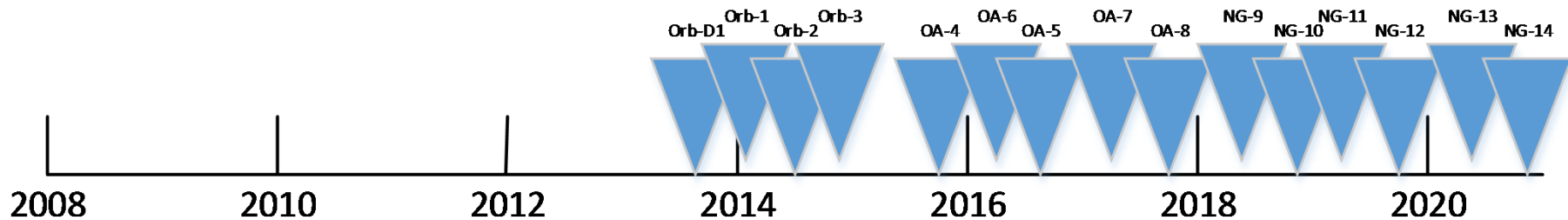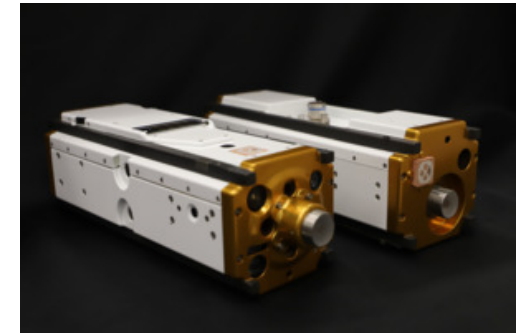
- **Cygnus has continuously improved upon capabilities delivered**

- **On top of spacecraft capability, Cygnus has successfully supported multiple secondary payloads**
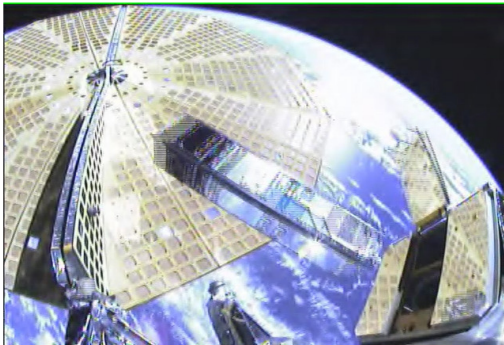
Nanoracks Deployer

Slingshot Deployer

Seeker Cubesat

Q & A

References

- **All Cygnus photos courtesy of NASA -** https://images.nasa.gov/
- **Nanoracks Deployer on Cygnus -** https://nanoracks.com/products/cygnus-deployment/
- **Hyper Giant Slingshot Deployer on Cygnus -** https://www.hypergiant.com/divisions/galactic/
- **Seeker and Kenobi Cubesats-** https://roundupreads.jsc.nasa.gov/pages.ashx/1130/Project%20X%20Seeker
- **State of DevOps Reports -** https://puppet.com/resources/?refinementList%5Btype%5D%5B0%5D=Report&page=1&configure%5BhitsPerPage%5D=18