Expendable Launch Vehicles (ELV):

Commercial Resupply NG-16

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Launchpad to Study the Earth, the Atmosphere and Beyond

Platform Overview

Commercial Resupply ELV

- Single-use rockets that are designed to deliver payloads to orbit
  - Stages are discarded sequentially
- Simpler architecture allows for high payload capacity
  - No fuel is reserved for recovery systems or reuse
- Widely used and ideal for scientific satellites, deep-space probes, and ISS resupply
- Proven reliability with decades of launches, being essential for missions without reuse constraints

Source: NASA, ScienceDirect

Brief History of ELVs

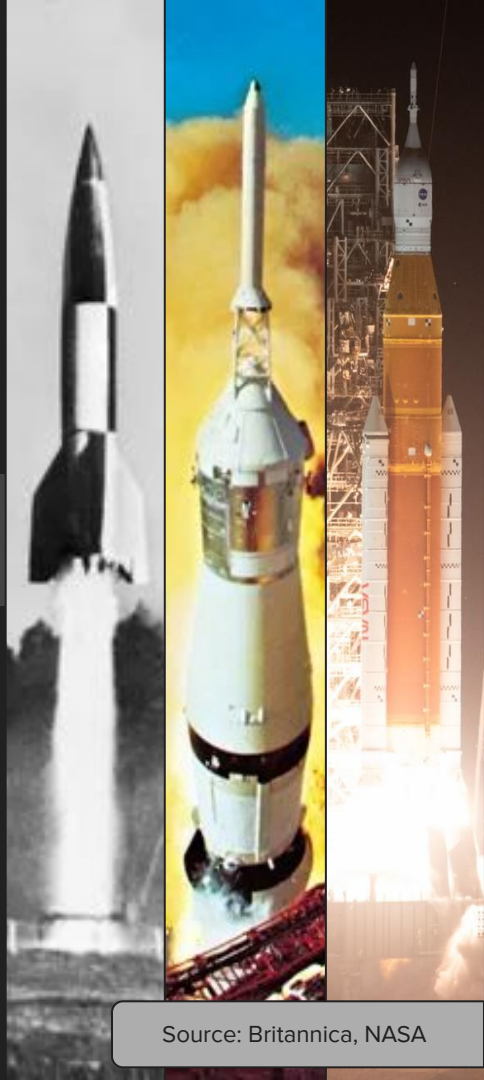
Pioneers of Space Exploration

- **Konstantin Tsiolkovsky** *Russia late 19th century*: Introduced the idea of multi-stage rockets
- **Hermann Oberth** *Germany 1923*: Explained and applied the mathematical theory of rocketry to early designs
- **Robert Goddard** *U.S. 1926*: Built and launched the first liquid-fueled rocket

Military Origins - Based on these early rocketry ideas, many spacecrafts are derived from 1950s and 60s intercontinental ballistic missiles (ICBMs)

Advancements in Design

- The WWII V-2 missile was a base for many spacecraft such as the Jupiter, Atlas, and Titan lines
- After John F. Kennedy announced America's ambition to reach the Moon in 1961, the Saturn I was fitted with five F-1 engines, creating the Saturn V
- The Saturn line was retired after Apollo-Soyuz in 1975 as the U.S. transitioned towards the reusable space shuttle
- The Artemis program shifts back to ELV's with the Space Launch System (SLS), designed to be evolvable for human and robotic missions to both the Moon and Mars



Source: Britannica, NASA

NASA WFF

- **Strategic Launch Infrastructure:** WFF's Mid-Atlantic Regional Space(MARS), co-located on Wallops Island, operates multiple ELV pads - LP-0A, LP-0B, and BC-2 (LB-0C) - supporting launches like Antares, Minotaur, and Electron
- **Quick Payload and Fuel Integration:** Upgraded facilities such as payload processing, fueling, and integration capabilities support medium-class orbital ELVs (up to 200,000 lb liftoff), allowing for multiple static-fires and launches per year
- **Extensive Instrumented Launch Range:** WFF maintains a fully equipped rocket range with radar, telemetry, tracking, and safety assets for both fixed and mobile launch zones, ensuring data collection and public safety

Source: NASA, Virginia Spaceport Authority

Commercial Resupply ELV

NG-16

S.S. ELLISON ONIZUKA

August 10, 2021 - Wallops Island, Virginia

Mission Overview

Key Details

- 16th Cygnus Mission under NASA’s CRS-2 Contract
- Launched aboard Northrop Grumman’s Antares 230+ rocket
- Delivered 3723 kg (8,208 lbs) of cargo to the ISS
- Payload included science experiments, crew supplies, and hardware
- Used a newer, upgraded version of the original Cygnus spacecraft
    - Named S.S. Ellison Onizuka in honor of the first Asian American astronaut

Source: Everyday Astronaut

Science Goals

Redwire Regolith Print
Bring less materials from Earth in future missions

- Micrograv ity 3D printing with simulated regolith

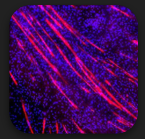
Kentucky Re-Entry Probe Experiment
Compare flight data to models for making new re-entry equipment

- Test new heat shield and collect flight data

Additional Science Payload

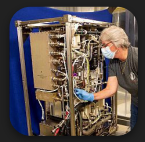
Prototype Infrared Payload (PIRPL)
Collect data for weapon detecting thermal sensors, study volcanic eruption/forest fire environmental impacts

- Use infrared imaging sensor PIRPL to collect data while in low Earth orbit



Cardinal Muscle Tests
Establish platform for researching sarcopenia

- Can micrograv ity be used as a research tool

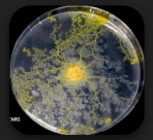


Four Bed CO2 Scrubber
Improve reliability and efficiency of CO2 removal systems for in space and on Earth

- Installing new Four Bed CO2 Scrubber on the ISS

Flow Boiling & Condensation Experiment
Transition to smaller and more efficient two-phase thermal management systems

- Testing two-phase systems in micrograv ity to compare with data on Earth



Blob: Mold in Micrograv ity
Observe Blob's (Physarum polycephalum) behavior in micrograv ity and compare with Earth

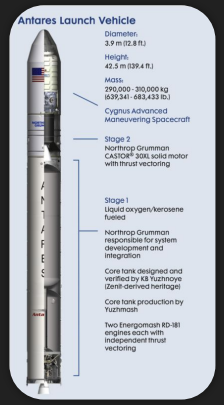
- Conducted by ESA ISS astronaut Thomas Pesquet and students on Earth

Source: eoPortal, NASA

Vehicle and Instrument Design

Review of Materials

- **Pressurized Cargo Module (PCM) by Thales Alenia Space:** aluminum-alloy structure, 27 m^3 volume with standard and enhanced variants
- **Service Module (SM):** GEOSTAR-based satellite bus structure with hydrazine/N_2O_4 propulsion (BT-4 engine), solar arrays and batteries
- **Antares 230+ Launch Vehicle:**
  - First stage: steel/liquid oxygen and RP-1 tankage, RD-181 Engines
  - Second Stage: Castor 30XL solid motor using HTPB/aluminum



Review of Assembly

- PCM and SM integrated in Dulles, VA, then mated onsite at Wallops Flight Facility
- Antares is assembled at Mid-Atlantic Regional Spaceport, Wallops Island VA, followed by attachment to Cygnus

Source: NASA, Northrop Grumman, Gunter's Space Page

Review of the Team

- **Aerospace Engineers:** Design spacecraft systems. Integrated the cargo and service modules.
- **Mechanical Engineers:** Build and test physical structures. Created fairings, stages, and tanks for launch.
- **Electrical/Avionics Engineers:** Handle power and electronics. Managed solar arrays, batteries, and SM avionics.
- **Propulsion Engineers:** Develop and test engines. Worked on RD-181, BT-4 thrusters, and Castor motor.
- **Systems Engineers:** Coordinate all subsystems. Ensured power, thermal, and GNC systems worked together.
- **Software Engineers:** Write and test flight code. Developed and verified GNC and mission software.
- **Structural Engineers:** Analyze stress and load. Tested PCM, fairings, and payload for launch durability.
- **Chemists/Material Scientists:** Choose and test materials. Selected alloys and built CO_2 scrubbers.
- **Payload Specialists and Scientists:** Prepare science equipment. Installed PIRPL, CO_2 scrubber, and KREPE probes.

Testing

Antares Rocket

Hotfire Test

- Firing the engines while strapped to the launchpad
  - Tests propulsion system, core stage, and launch complex
  - Demonstrates launch procedures, loading sequence, countdown, engine ignition, shutdown commands, and throttle settings

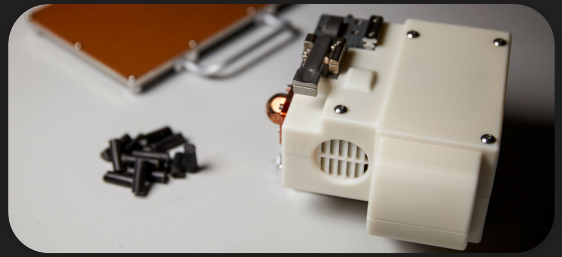
Cygnus Craft

Pre-Launch Testing

- Integration in a class 100,000 clean room
- Structural, environmental, and GNC (guidance/navigation/control) checks both in Dulles and Houston mission centers
- Then shipped to Wallops Flight Facility

Source: Spaceflight Now

Data Collection



Instrumental and Sensor-Based Measurements

- **Muscle Tests and Sarcopenia Platform:** Utilized force sensors, electromyography (EMG), and video tracking to measure muscle contractions and atrophy progression
- **4-Bed CO_2 Scrubber and Thermal Systems:** Logged real-time CO_2 concentrations, flow rates, temperature, and power consumption at regular intervals

Material and Structural Data Sampling

- **Redwire Regolith Print:** Collected 3D-printed sample data (dimensions, topology) onboard ISS for later strength and microstructure tests on Earth
- **Kentucky Re-Entry Probe:** Integrated heat flux gauges, temperature sensors, strain gauges, and accelerometers in the heat shield and probe body to gather re-entry data during descent

Image and Video-Based Observation

- **PIRPL Infrared Imaging:** Captured continuous infrared frames to monitor thermal anomalies like volcanoes and fires
- **“Blob” (Physarum polycephalum) Experiment:** ESA astronaut used time-lapse cameras onboard ISS, students used ground controls with oats to compare exploration behavior and 3D movement

Environmental and Two-Phase Thermal Logging

- **Flow Boiling and Condensation Module:** Logged pressure, temperature, flow rates, and phase-change visual records via onboard sensors and camera feeds, allowing for Earth vs. microgravity comparison

Source: eoPortal

Launch

Initial Schedule

Date: August 10, 2021

Time: 5:56 p.m. ET

Location: Mid-Atlantic Regional Spaceport (MARS) Pad 0A - Wallops Island, VA

Rendezvous: August 12, 2021

Schedule Updates

Time: 6:01 p.m. ET

Reason: Minor ground support issue

Official Launch

Date: August 10, 2021

Time: 6:01 p.m. ET

Location: Mid-Atlantic Regional Spaceport (MARS) Pad 0A - Wallops Island, VA

Rendezvous: August 12, 2021

Updates:

- 8:46 p.m. - Solar arrays deployed
- August 12th, 6:07 a.m. - Arrival on the ISS
- 9:42 a.m. - Bolted to Unity module, set to remain for 3 months

Source: Northrop Grumman

Conclusions

Data Interpretation

- **Muscle Tissue Chips:** 7 days in microgravity caused shifts toward fatty acid metabolism and cell death; IGF-1 treatment reduced atrophy effects
- **4-Bed CO_2 Scrubber:** Operated for over a year with low dust buildup >1% CO_2 purity, surpassing reliability targets
- **Regolith 3D Printing:** Three printed regolith plates were returned showing strong structural integrity for further Earth-based testing

Mission results

- NG-16 delivered 8,200lbs of cargo on schedule
- CO_2 scrubber installed and activated by ISS crew
- Redwire printer and regolith operated successfully in orbit
- KREPE probe completed re-entry data transmission
- Blob experiment carried out with ISS astronaut and students
- All payload, launched, operated, and returned as planned

Were the Science Goals Met?

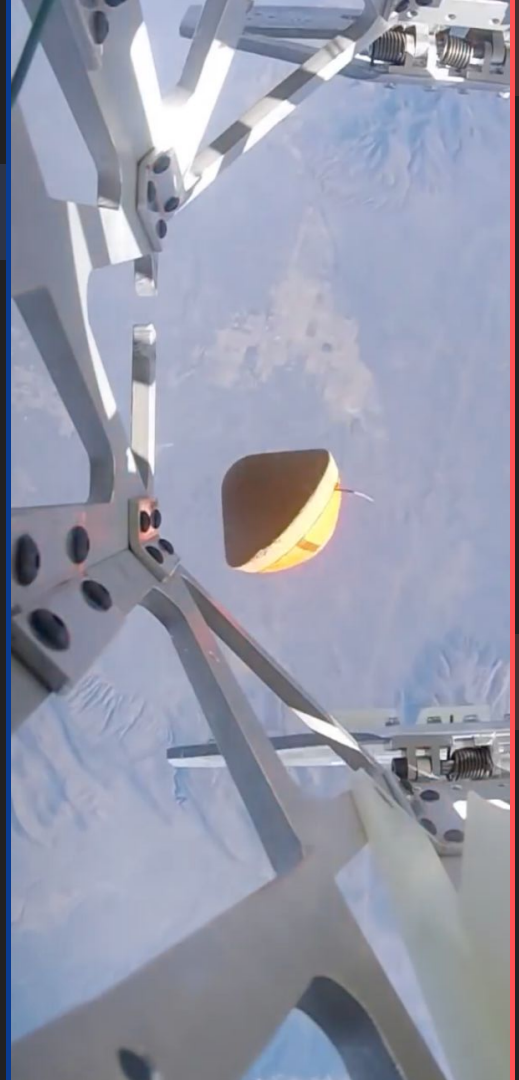
- All science goals were achieved or successfully advanced
- Biological, physical, and materials research produced actionable metrics
- Life-support and construction technology returned performance data essential for future missions

Source: NIH, 3D Printing Industry, NASA

Future Studies

Preparing for Future Missions

- Continue preparing for missions to the Moon and Mars
  - Improving size, weight, and efficiency of spaceflight technology and cargo
  - Improving quality of life in space



Continuing to Innovate

- Pushing for greater efficiency and safety with new technology as it is tested and developed
  - CO_2 removal systems
  - Thermal management
  - Rocket boosters
  - Launch complexes

Expanding Data

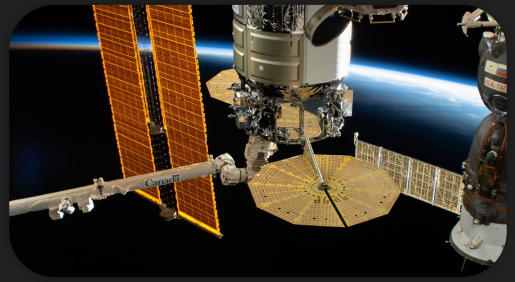
- Provide scientists and engineers with realistic data and models
  - Effects of microgravity
  - Re-entry

Source: Spaceflight Now

Fun Facts

New Insights

- After leaving the ISS, Cygnus used a “Slingshot” system to deploy mini-satellites into higher orbit
- NG-16 carried parts for a second solar array retrofit on the ISS, improving its power-producing capability
- Expedition 65 crew enjoyed fresh food and care packages, including a pizza night, after unloading supplies



Further Questions

- What happens if one of the experiments fails during flight? Are there backups in place?
- How does NASA decide which experiments are chosen for resupply missions like NG-16?
- What lessons from the CO_2 scrubber could improve life support systems on future Mars missions?

Source: AmericaSpace, SEOPS Space

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