Lockheed Martin C-130
The Hundred-Year Airplane

Tony Hays
www.adac.aero
ahays@alum.mit.edu
“I anticipate that 100 years will pass between the first flight of the C-130, and the last flight of an aircraft of this design”

Bart Osborne

V-P Engineering, Lockheed-Georgia Co.

c. 1998
C-130 First flight 1954-08-23

- The Department of Defense awarded more than $1.5 billion in funding for the first 21 C-130J aircraft on the multiyear award. The overall award is worth more than $3 billion. Aircraft purchased through the C-130J Multiyear III award will be delivered between 2021 and 2025, and will be built at Lockheed Martin's Marietta, Georgia, facility.

- Average life of a C-130 is > 28 years

- USAF C-130s will be operational at least until 2053

- 2024-04 Order backlog is ~100 aircraft with 50 anticipated orders. With production rate of 28 aircraft/year, production will likely pass 2030
What other USAF airplane type can lay claim to be a hundred-year airplane?
Boeing B-52

B-52 first flight  1952-04-15

Likely to remain in service until 2060*

* https://www.defensenews.com/air/2024/02/20/tinker-air-force-base-readies-for-b-52-upgrades-as-engines-tested/#text=These%20developments%20will%20mark%20critical,B%20D52H%20was%20first%20introduced.
C-130 Highlights

- Longest continuous production run for any military aircraft
- To date, more than 60 years of service
- Originally designed for transport of
  - Troops
  - Medevac
  - Cargo
C-130 Highlights

• Additional roles
  – Gunship (AC-130J)
  – Aerial refueling (KC-130J)
  – Maritime patrol (HC-130)
  – Weather reconnaissance (WC-130)
  – Airborne assault (KC-130T)
  – Special Operations (C-130J-SOF)
  – Search and rescue (KC-130T)
  – Scientific research support
  – Aerial firefighting
  – Commercial freighter (L-100)
• Requirements for turboprop tactical transport
• Development of C-130 (Models A-H)
• Applications outside original specs.
• Development of C-130J
• More applications outside original specs.
USAF Requirements

- **1951-02-02** USAF issues General Operating Requirement (GOR) for military transport
  - Payload of 92 pax (or 72 combat troops, or 64 paratroopers) with range of 3,704 km (2,000 nmi)
  - Max. payload 13,607 kg (30,000 lb) with range of 2,778 km (1,500 nmi)
  - Flight at 232 km/hr (125 kt) for paradrops
  - Rear loading ramp
  - Short + Rough field operation
- **Five bidders were:** Boeing, Douglas, Lockheed, Chase Aircraft, Airlifts Inc.
• Requirements for turboprop tactical transport
• **Development of C-130 (Models A-H)**
• Applications outside original specs., e.g.
• Development of C-130J
• More applications outside original specs., e.g.
  – Missile/drone launch and recovery platform
Lockheed Design Team

- Willis Hawkins (Head of Advanced Design)
  - Eugene Frost
  - Art Flock
  - E.A. Peterman
  - E.C. Frank
  - Dick Pulver
Proposal Submission

- Hawkins prepared 130 page proposal
- Submitted to Hall Hibbard, VP Engineering
  - Requested review by Kelly Johnson, who said “Hibbard, if you send that in [to the Air Force], you’ll destroy the Lockheed Company”¹
- Hibbard signed proposal letter anyway

¹ AWST 2021-12-06
C-130 First Flight 1954-08-23

Enroute from Burbank to Edwards AFB

Source: Lockheed
YC-130 First Flight 1954-08-23

https://www.youtube.com/watch?v=sGxuu1XpbAA
Allison T56 Turboshaft

- Max power: 3,240 kW (4,350 shp) flat rated to 3,100 kW (4,100 shp)
- Power/weight ratio: 4.52 kW/kg (2.75 shp/lb)
T-56 Start Using Prop Wash

Run engine at high power

Set prop at coarse pitch

https://www.the-blueprints.com/blueprints/modernplanes.lockheed/80286/view/lockheed_c-130h_hercules/
C-130 and C-130-30

C-130E/H/J Cargo hold length: 12.5 m (41ft)
Max. payload: 19.090 kg (42,000 lb)

C-130-30E/H/J Cargo hold length: 16.9 m (56ft)
Max. payload: 19,958 kg (44,000 lb)

https://www.af.mil/About-Us/Fact-Sheets/Display/Article/1555054/c-130-hercules/

Source: Lockheed
C-130 Payload Bay

Width and height allegedly based on M-551 Sheridan light tank concept (although tank didn’t enter service until 1960s)

Length based on US railway boxcar

Marietta, GA, production line in 1956
C-130 Main Landing Gear

Raised and lowered by parallel jackscrews driven by hydraulic motor

Small MLG blister
C-130 Fuel Management

Source: Lockheed

Tactical Ops.
Landing
Wing bending relief fuel
C-130 Heavy Landing

https://www.youtube.com/watch?v=BHSACq-HeoA
C-130 Water Bomber Wing Failure

Failure due to poor inspection, maintenance, and repair, and NOT due to aircraft exceeding design loads

https://www.youtube.com/watch?v=-A4QZAxrb28
C-130 Air Drop

https://fas.org/man/dod-101/sys/ac/c-130-dfst9110084.jpg
C-130 LAPES

Low-Altitude Parachute-Extraction System

https://www.youtube.com/watch?v=dgg3iRaVvbw&feature=emb_title
• Requirements for turboprop tactical transport
• Development of C-130 (Models A-H)
• Applications outside original specs., e.g.
  – Corona capsule recovery
  – Fulton personnel and equipment recovery
  – Hostage recovery
  – Gunship
• Development of C-130J
• More applications outside original specs
Project CORONA

- Developed by CIA in 1950s
- Approved by President Eisenhower in 1958-02
- Lockheed selected as prime contractor
- First 13 mission attempts failed
- Over 800,000 photos taken
- Declassified 1995-02
Project CORONA

Objectives:
- Annual and semi-annual search
- Priority targets
- Mapping, charting, and geodesy

Payload Data:
- Two convergent, f/3.5, 24 in. fl.
- Pan cameras
- Stellar-terrain camera
- 3,1500 ft x 70mm film
- Frame size 7.4 x 119 NM
- Resolution 6-10 ft
- Coverage 7 million sq nm/mission
- Two recovery vehicles

Orbital Data:
- Inclination 60-110 deg
- Average perigee 100 NM
- Average apogee 150 NM
- Mission life: 19 days

Booster:
- Thor/Agena
Project CORONA

KH-4B CORONA ("J3" Model)
Agena-D service module

TOP VIEWS

SIDE VIEWS

Human Figure (To Scale)

0 1 2 3 meters

https://upload.wikimedia.org/wikipedia/commons/a/ac/KH-4B_CORONA-J3.jpg
Project CORONA

https://en.wikipedia.org/wiki/CORONA_(satellite)
JC-130A CORONA Capsule Recovery

Watch
00:00 – 01:30
07:00
07:30

Buyout Footage.com
Historical Footage in True HD

https://www.youtube.com/watch?v=Q2YQqAnEN_0
JC-130B Snagging a Capsule

Loop with brass hooks spliced in

Conical extension with reinforcement lines snagged by JC-130 hooks

For more information, see
Fulton Recovery System

- 1950 Testing started on method for retrieving CIA operatives
- Initial testing using instrumented dummies, then live pigs*
- System dropped from aircraft included
  - Harness
  - 150 m (500 ft) braided nylon line
  - Dirigible shaped balloon with He inflator
- 1962-05-28 first operational use: two agents parachuted to abandoned Soviet arctic drift station. Pickup made on 1962-06-02
- 17 years of use, only one fatal accident

*Biggest problem: placating an angry pig after retrieval
Fulton Recovery System

Deflector wires

Tubular steel horns

“Sky anchor” locked line to aircraft
Fulton Recovery System
Operation Thunderbolt

- 1976-06-27 Air France A300 Tel Aviv – Paris with 248 pax hijacked by two Palestinian Liberation Front (PLF) members and two German Revolutionäre Zellen (RZ) terrorists, and flown to Entebbe, Uganda
- PLF demanded hostages be exchanged for 53 imprisoned PLF members
- 148 non-Israelis released by hijackers
- 106 hostages remained (94 pax + 12 crew)
Operation Thunderbolt

• Four Israeli Defence Force (IDF) C-130s carried 245 commandos in raid on Entebbe airport

• Of 106 hostages, four killed
• Israeli unit commander, Yonatan Netanyahu*, also killed

* Eldest brother of Benjamin Netanyahu
Operation Eagle Claw

1979-11-04: Students invade U.S. embassy in Tehran: 52 Americans held as hostages

• 1980-04-24 First attempt at rescue: eight RH-53Ds to fly to desert staging area to be refueled by four EC-130Es on the ground, with six required to be available for operational success.

• Helicopters would fly to second staging area for raid on Tehran
  – Take control of Tehran airport
  – Release hostages
Operation Eagle Claw

• Only five helicopters arrive at staging area in operational condition (plus one non-operational)
  – Hydraulic failure
  – Caught in sandstorm
  – Cracked rotor blade

• Mission abandoned

• During withdrawal, RH-53 collides with C-130 on ground
  – 8 servicemen killed

• One passing Iranian killed by US gunfire.
Shahid Shoroudi (Amjadieh) Stadium

- Latter half of 1980: second attempt planned to release hostages by landing a C-130 in a soccer field (across the road from embassy) in Tehran

YMC-130H  Credible Sport JATO Operations

https://www.youtube.com/watch?v=sdZtArJca6s
Shahid Shoroudi (Amjadieh) Stadium

- 1980-10 Iraq invades Iran. Secret negotiations started with Algeria as intermediary
- 1981-01-20 hostages released

Two CH-53Es with external loads refueled by KC-130 over Gulf of Aden

AC-130 Gunship

https://www.youtube.com/watch?v=7lrfdzU8k4k&t=55s
My job: when aircraft was approaching, turn tape recorder on. After landing, turn tape recorder off.
• Requirements for turboprop tactical transport
• Development of C-130 (Models A-H)
• Applications outside original specs., e.g.
  – Corona capsule recovery
  – Fulton personnel and equipment recovery
  – Hostage recovery
  – Gunship
• **Development of C-130J**
• More applications outside original specs., e.g.
  – Missile/drone launch and recovery platform
C-130K-30

- UK MoD ordered 66 Hercules C.Mk 1
- 1967 entered service
- 1978 converted 30 aircraft from C.Mk 1 to C.Mk 3 (i.e. C-130-30)

https://www.raf.mod.uk/aircraft/c-130j-hercules/

C-130J Development

• 1987 Studies started on upgrading C-130
• 1993-12 UK MoD identified need for C-130 replacement
• Placed orders for 25 C-130Js
  – Required certification to FAR Part 25 (similar to UK CAR Part 25)
• Manager: Dr. Bill Mikalowski
• Estimated development cost ~ $200M
• First flight 1996-04-05
C-130J

Major upgrade features

- Engine: R-R Allison AE.2100
- Propellers: Dowty R391 composite, swept 6-bladed
- Flight deck: Glass cockpit with head-up display
- Composite flaps
- Databus: MIL-STD-1553
# C-130H vs. C-130J Comparison

<table>
<thead>
<tr>
<th></th>
<th>C-130H</th>
<th>C-130J</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed (ktas [M])</td>
<td>318 [0.52] @20,000 ft</td>
<td>362 [0.59] @22,000 ft</td>
</tr>
<tr>
<td>Ceiling (ft) with 19,090 kg (42,000 lb) p/l</td>
<td>23,000</td>
<td>28,000</td>
</tr>
<tr>
<td>MTOGW (kg (lb))</td>
<td>69,750 (155,000)</td>
<td>74,393 (164,000)</td>
</tr>
<tr>
<td>Max. allowable payload (kg (lb))</td>
<td>19,090 (42,000)</td>
<td>19,090 (42,000)</td>
</tr>
<tr>
<td>Max. normal payload (kg (lb))</td>
<td>16,590 (36,500)</td>
<td>15,422 (34,000)</td>
</tr>
<tr>
<td>Range at max. normal payload (nmi)</td>
<td>1,050</td>
<td>1,800</td>
</tr>
<tr>
<td>Range with 35,000 lb payload (nmi)</td>
<td>1,300</td>
<td>1,600</td>
</tr>
<tr>
<td>Crew (pilots/flt engineer/navigator/loadmaster)</td>
<td>2/1/1/1</td>
<td>2/0/0/1</td>
</tr>
<tr>
<td>Cost (FY 2017 then year $M)</td>
<td>$30.1</td>
<td>$75.5</td>
</tr>
</tbody>
</table>

No flight engineer
No navigator

[https://www.af.mil/About-Us/Fact-Sheets/Display/Article/1555054/c-130-hercules](https://www.af.mil/About-Us/Fact-Sheets/Display/Article/1555054/c-130-hercules)
Rolls-Royce AE 2100

Identical physical fit and thrust centerlines as Allison (now R-R) T56 engine

- Max. power: 3,458 kW (4,637 shp)
- Power/weight ratio: 4.4 kW/kg (2.7 shp/lb)
Rolls-Royce AE 2100

2-stage power turbine drives propeller
2-stage compressor turbine
14-stage compressor
Propeller gearbox
T-56 Start Using Prop Wash

https://www.the-blueprints.com/blueprints/modernplanes/lockheed/80286/view/lockheed_c-130h_hercules/
Dowty R391 Propellers

• Mixture of carbon and glass fiber with inner core of polyurethane foam
• With CRP, can reinforce non-uniform radial loads of swept blades
• ARA-D/A airfoil section

http://dowty.com/products/military-aircraft/
Propeller Cross-flow Effects

- Higher power loading of Dowty props
  - Increased cross flows in region of flaps
  - Asymmetric flow separation in flap region
  - Violent roll at power-on stall
  - FAA required increase in power-on $V_s$
  - Corresponding increase in $V_2$ (takeoff safety speed)
  - Increased TOFL
C-130H Cockpit

https://www.flickr.com/photos/28042007@N07/4167333874
C-130J Glass Cockpit

HUD
Mechanical Displays
Primary Flight Display (PFD)
Engine Monitor

Advisory Caution and Warning System
HUD
Weather Radar
Aeronautical Chart
C-130J Head Up Display (HUD)

- **Airspeed**
- **Altitude**
- **Heading**
Heading Indicator

Numbers increase to the left

Numbers increase to the right
Collins CNS/ATM Upgrade to C-130H

Mechanical Displays
Combined PFD & Weather Radar
Aeronautical Chart

Combined PFD & Weather Radar
Airfield Approach Plate
Engine Monitor

Cockpit upgrade to older model of C-130 (over 370 aircraft modified, or to be modified)
C-130J MIL-STD-1553 Databus

Advertisement from COTS Journal

1153 databus links avionics, Full Authority Digital Engine Control (FADEC)
C-130J Current Variants

C-130J-30
COMBAT DELIVERY
C-130J Current Variants

KC-130J
AERIAL REFueling

Cobham Series 48 AR Pods
KC-130J Refuelling F-35

View from 01:30-02:51
Connection at 02:20
02:51

https://www.youtube.com/watch?v=2bJ8Q8iaN4c
C-130J Current Variants

C-130J-SOF
INTERNATIONAL
SPECIAL OPERATIONS
The C-130J-SOF provides specialized intelligence, surveillance, and reconnaissance (ISR) support, along with infiltration, exfiltration, and re-supply of special operations forces (SOF) and equipment in hostile or denied territory.

With added special mission equipment options, the C-130J-SOF may be configured to execute armed overwatch, precision strike, helicopter and vertical lift aerial refueling, psychological operations, high-speed/low-signature airdrop resupply, personnel recovery, forward area refueling point (FARP) operations, and humanitarian/rescue operations.

AC-130J Ghostrider

- **Crew:**
  - 2 pilots
  - 2 combat systems operators
  - 3 enlisted gunners
- **Weapons**
  - 30 mm GAU-23 chain gun
  - 105 mm M102 howitzer
  - 2 x 4 Wing-mounted GBU-39 small dia. precision glide bombs
  - 10 AGM-176 Griffin laser-guided missiles (launched through rear cargo door)

Source: Chrissy Cuttita, USAF
Modular Airborne Fire-Fighting System (MAFFS) can be used on any model C-130
C-130J Current Variants
LM-100J is commercial variant of C-130J-30

Over 50% increase in range

https://www.lockheedmartin.com/content/dam/lockheed-martin/aero/documents/C-130J/C130%20Brochure_%20Final%202015.pdf
• Requirements for turboprop tactical transport
• Development of C-130 (Models A-H)
• Applications outside original specs., e.g.
  – Corona capsule recovery
  – Fulton personnel and equipment recovery
  – Hostage recovery
  – Gunship
• Development of C-130J
• More applications outside original specs., e.g.
  – Missile/drone launch and recovery platform
Boeing GBU-39 Small Dia. Bomb

- 110 kg (250 lb) precision guided glide bomb
- 16 kg (36 lb) AFX-757 explosive
- GPS-guided with 5-8 m (16-26 ft) CEP
- Up to 60 nmi standoff distance

- AC-130 can carry 2 racks of 4 missiles each
- Can be carried on other aircraft types
Griffin Missile

Griffin® B Block II missile

- Selective Availability
- Anti-Spoofing module

- Small and light:
  - 43 inches
  - 33 lbs

- Precise:
  - SAASM GPS/INS
  - Semi-active laser (SAL)

- Reliable:
  - Tube carriage/launch
  - Proven component heritage

- Lethal with low collateral damage:
  - 13 lb blast fragmentation warhead
  - Warhead fusing options:
    - Height of Burst (HOB)
    - Point Detonate (PD)
    - Delay
    - Confined lethality

- Cockpit selectable options provide real-time flexibility / assessment
  - Fuze settings: PD, HOB, Delay
  - Laser PRF codes
  - Built In Test (BIT)

Range:
4.3 nmi (8.0 km) from surface
10.6 nmi (20.1 km) from altitude

https://www.globalsecurity.org/military/systems/munitions/agm-176.htm
Raytheon Griffin Missile Launcher

Raytheon AGM-175A Griffin Missile Launch

https://www.youtube.com/watch?v=mk1Me_AKxxU
Dynetics Gremlins Swarm Drones

https://www.youtube.com/watch?v=BF1sJjk66rU
X-61A Gremlins Test Flight in 2019-11

Potential Applications

- Intelligence, Surveillance and Reconnaissance (ISR)
- Mobile target attack
- Suppression of Enemy Air Defenses (SEAD)
- Close Air Support (CAS)

Mission radius/loiter
25 nmi/4.0 hr  300 nmi/>1.0 hr
Payload 145 lb
Max. cruise M 0.6

2019-11 Launched from C-130A, but parachute failed to open

Dynetics Selects Advanced Navigation For Gremlins X-61 UAV

CASE STUDY

Dynetics

https://www.advancednavigation.com/case-studies/dynetics-selects-advanced-navigation-for-gremlins-x-61-uav/
Airborne Tactical Laser Weapon

Warfighter Benefit
- Ultra-precision target engagement
- Speed of light engagement
- Reduced collateral damage
- Scalable effects
- Covert - Plausible deniability
- Improved ISR supporting BMC4I
- Encompasses entire kill chain

Attributes
- 100KW-class high energy laser
- Integrated in a multi-mission C-130 type airframe
- 10 Km+ effective range
- 20+ targets per mission

Business Opportunities
- Advanced Tactical Laser (ATL)
- Extended User Evaluation (EUE) FY08
- FY10 POM Submittal
- FY12 Projected Program Start
AC-130J with Tactical Laser

Testing on AC-130J in 2022

~ 60 kW laser

https://www.forbes.com/sites/davidhambling/2020/05/15/special-forces-test-laser-gunship-for-covert-strikes/#4ef67eda3508
Special Operations Command MC-130J

2021-05-19 Special Operations Forces (SOF) Industry Conference

Potential use for
• Infiltration/extraction of special operations forces
• Refuel helicopters and tilt-rotor aircraft

U.S. Special Operations Command (USSOCOM) plan for amphibious configuration

https://worlddefense.com/threads/amphibious-mc-130j-transport-is-on-special-operations-commands-wishlist.8306/
What Made the C-130 Successful?

- **USAF Requirements**
  - “Right-sized” requirements for tactical transport
  - Rear loading ramp
  - Short + Rough field operations

- **Original Design**
  - Advanced turboprop (first in US)
  - Payload bay sized for light tank
  - Cockpit with panoramic view
What Did We Cover?

- Requirements for turboprop tactical transport
- Development of C-130 (Models A-H)
- Applications outside original specs.
- Development of C-130J
- More applications outside original specs.
Further Reading and Weblinks

“Lockheed Aircraft since 1913”, René Francillon, Putnam, 1987
“Mighty Hercules, The First Four Decades”, Lindsay Peacock, et al., RAF Benevolent Fund, 1994

Farnborough Air Show 2018

LM-100J at Farnborough 2018

View from 1:40 - 2:10

https://www.youtube.com/watch?v=xbwM-nBKVAl

Capt. Wayne Roberts

5:40
Thanks for your interest

A pdf of this presentation will be available at https://www.adac.aero/class-presentations