Università degli Studi di Padova – Dipartimento di Ingegneria Industriale

Corso di Laurea in Ingegneria Aerospaziale

Relazione per la prova finale «Hubble e James Webb a confronto: uno studio sulla strumentazione elettronica degli osservatori spaziali»

Tutor universitario: Prof. ANDREA BEVILACQUA

Laureando: *MATTEO CASARO*

Padova, 14/03/2023

Il 24 aprile 1990
Hubble Space Telescope

↓

PRIMO OSSERVATORIO SPAZIALE

VS

Il 25 dicembre 2021
James Webb Space Telescope

↓

ULTIMO OSSERVATORIO SPAZIALE

STRUMENTAZIONI ELETTRONICHE:

CONFRONTO TRA LE STRUMENTAZIONI USATE PER I DUE CON FOCUS SULLE INNOVAZIONI

HUBBLE SPACE TELESCOPE (HST)

LANCIO: 1990-04-24 a bordo di Space Shuttle Discovery
ORBITA: Attorno alla Terra
PRIME IMMAGINI: 25 giugno 1990
MIRROR: 2.4 m => collecting area: 4 m^2

Possibili interventi di riparazione e modifica nello spazio

OBIETTIVO: raccogliere immagini dello spazio per studiare l'universo, come è stato creato e come si è evoluto

5 strumenti a bordo:

- **WFC3** (wide field camera 3)
- **ACS** (advanced camera for surveys)
- **COS** (cosmic origins spectrograph)
- **STIS** (space telescope imaging spectrograph)
- **NICMOS** (near infrared camera and multi object spectrometer)

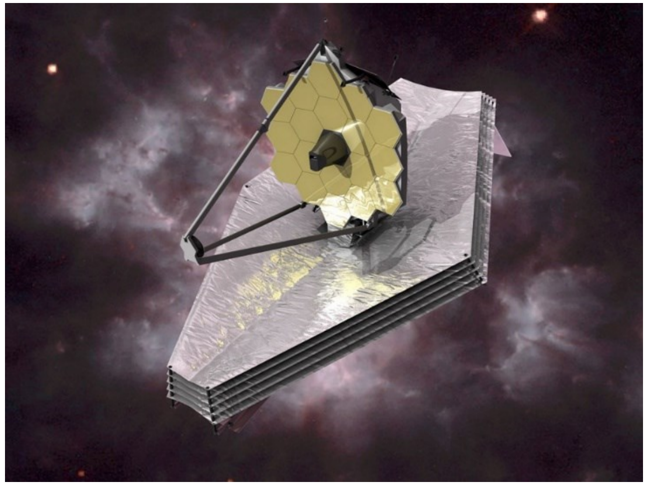
EAGLE NEBULA: «PILLARS OF CREATION»

JAMES WEBB SPACE TELESCOPE

LANCIO: 2021-12-25 a bordo di razzo Ariane 5
ORBITA: in orbita attorno al Sole, nel secondo punto di Lagrange L2
PRIME IMMAGINI: 2022-07-11
MIRROR: 6.5 m => collecting area: 25.4 m2

4 OBIETTIVI PRINCIPALI:

- Cercare le prime galassie formatesi dopo il Big Bang
- Determinare l’evoluzione delle galassie
- Osservare la formazione delle stelle
- Misurare le proprietà fisiche e chimiche dei sistemi planetari



4 strumenti montati nell’ISIM:

- **NIRCam** (near-infrared cam)
- **NIRSpec** (near-infrared spectrograph)
- **MIRI** (mid-infrared instrument)
- **FGS/NIRISS** (fine guidance sensor/near infrared imager and slitless spectrograph)

GALASSIA NGC1433

WIDE FIELD CAMERA 3 (WFC3)

IMAGER PRINCIPALE HST

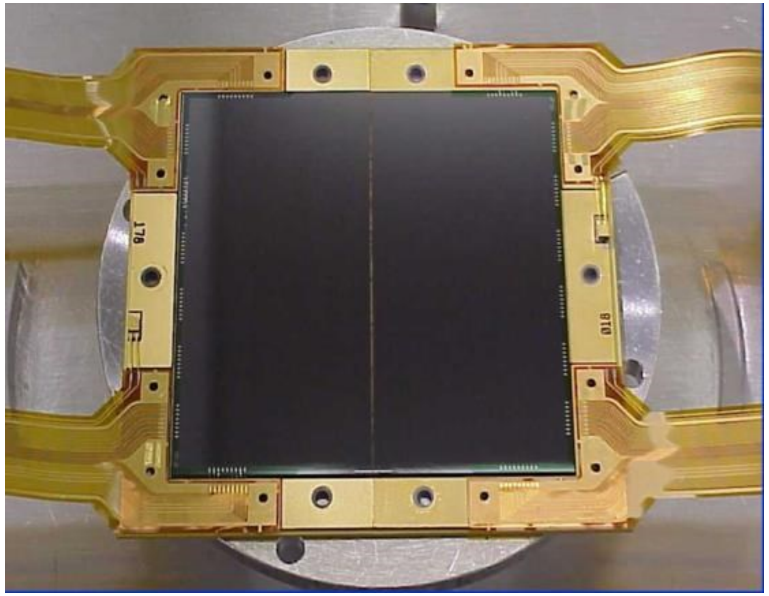
INSTALLAZIONE: Servicing Mission 4 (SM4, Maggio 2009);
sostituisce Wide Field and Planetary Camera 2 (WFPC2)

DUE CANALI:

1. **UVIS:** per luce ultravioletta e visible
2. **NIR:** per luce del vicino infrarosso

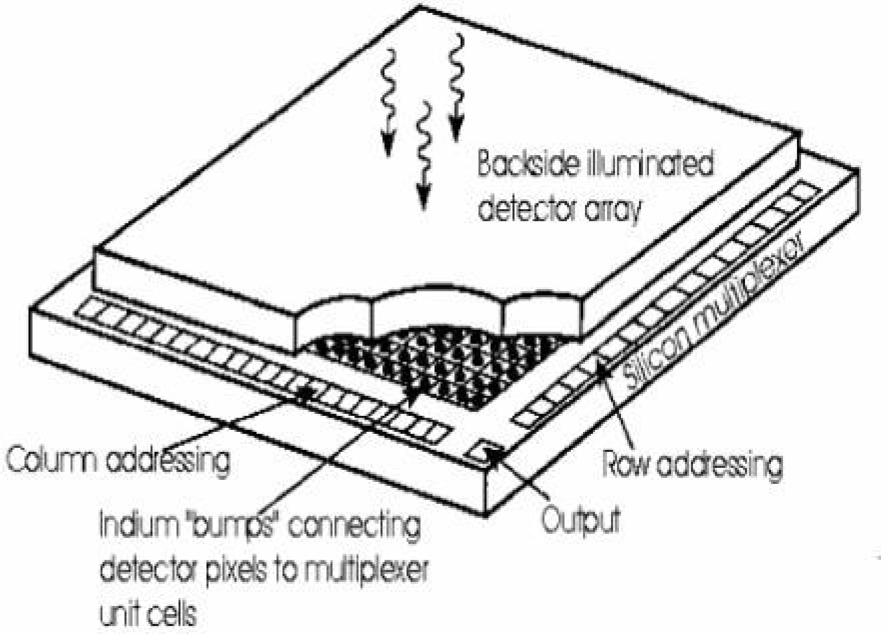
WFC3: CANALE UVIS

Canale UVIS: CCD al silicio (16 megapixel, alta sensibilità, basso rumore).



- **FOV**: 160 x 160 arcsecondi (~7,11 arcmin2)
- **intervallo di lunghezze d'onda**: 200-1000 nm
- **risoluzione angolare** ("pixel scale"): 0,040 arcsec/pixel
- **OBIETTIVI**:
  - Archeologia stellare
  - Distribuzione delle galassie ad alto redshift

Canale NIR: array da 1 megapixel realizzato con **HgCdTe**



- **FOV:** 123 x 137 arcsecondi (~4,68 arcmin2)
- **intervallo di lunghezze d'onda**: 850-1700 nm
- **risoluzione angolare** ("pixel scale"): 0,13 arcsec/pixel
- **OBIETTIVI**:
  - Galassie a più alto redshift
  - Individuare possibili acqua e ghiaccio su Marte

SECONDO IMAGER HST

INSTALLAZIONE: Servicing Mission 3B (SM3B, marzo 2002);
sostituisce Faint Object Camera (FOC)

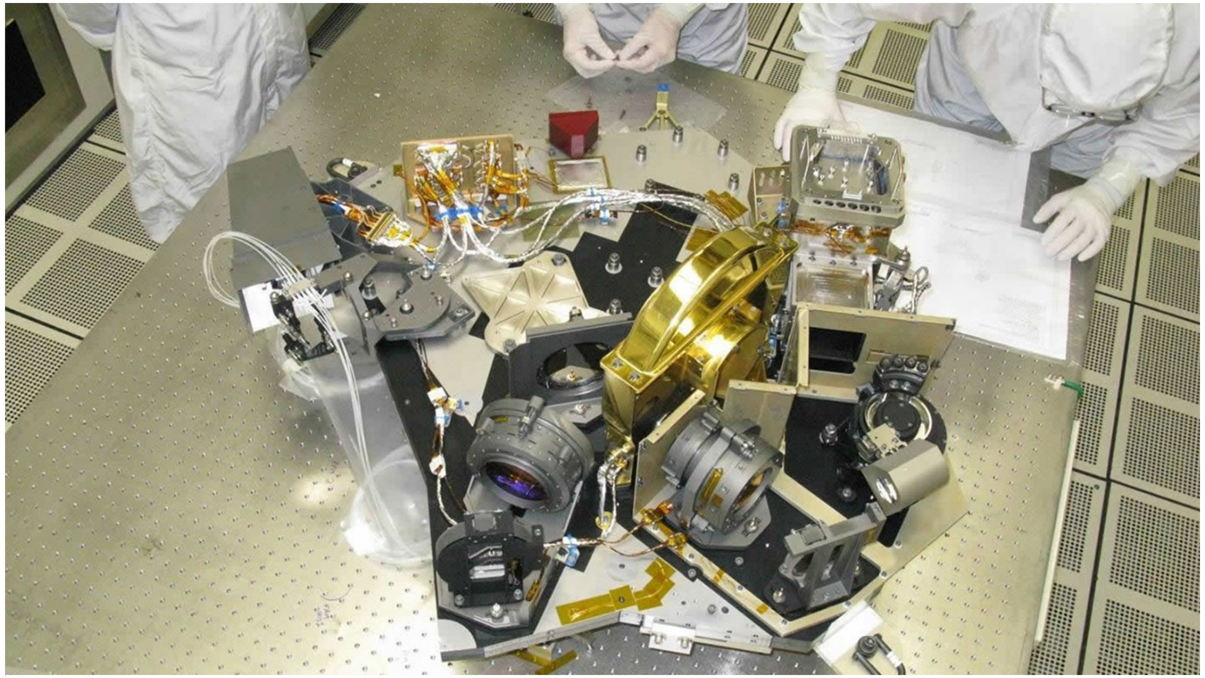
TRE CANALI:

1. **WFC** (Wide Field Channel)
2. **HRC** (High Resolution Channel)
3. **SBC** (Solar Blind Channel)

ACS: CANALI

- **Wide Field Channel (WFC):** VIS -> Near IR
  - **FOV**: 202 × 202 arcsec2 (~11,33 arcmin2)
  - **FORMATO IMMAGINE**: 2 × 2048 × 4096 pixel
  - **PIXEL SCALE:** 0.050 arcsec/pixel
  - **Intervallo lunghezze d'onda**: 350 - 1100 nm
- **High Resolution Channel (HRC):** Near UV -> Near IR, NON OPERATIVO (guasto elettrico)
  - **FOV**: 29 × 26 arcsec2
  - **FORMATO IMMAGINE**: 1024 × 1024 pixel
  - **PIXEL SCALE:** 0.025 arcsec/pixel
- **Solar Blind Channel (SBC)**: UV
  - **FOV**: 34,6 × 30,5 arcsec2
  - **FORMATO IMMAGINE**: 1024 × 1024 pixel
  - **PIXEL SCALE:** 0,034 arcsec/pixel
  - **Intervallo lunghezze d'onda**: 115-170 nm

IMAGER PRINCIPALE JWST



10*2048*2048 ARRAY HgCdTe

range di lunghezze d'onda:
600 - 5000 nm

5 modalità di osservazione:

- IMAGING
- CORONAGRAPHIC IMAGING
- WIDE FIELD SLITLESS SPECTROSCOPY:
- TIME-SERIES IMAGING + GRISMS TIME SERIES

NIRCam suddiviso in **2 bande:**

- **SHORT WAVELENGTH BAND**:
  - **numero di array**: 4 per lato (=8 in totale) => MAGGIORE RISOLUZIONE
  - **intervallo d'onde**: 600 - 2300 nm
  - **risoluzione angolare** ("pixel scale"): 0,0317 arcsecondi/pixel
- **LONG WAVELENGTH BAND**:
  - **numero di array**: 1 per lato (=2 in totale) => MINORE RISOLUZIONE
  - **intervallo d'onde**: 2300 - 5000 nm
  - **risoluzione angolare** ("pixel scale"): 0,0647 arcsecondi/pixel

NIRCAM: TECNOLOGIA HGCDTE

NUOVO DESIGN → **TEMPERATURA PIÙ BASSA**

MINORE DARK CURRENT

MINORE PROBABILITÀ GUASTI

MAGGIORE TEMPO DI ESPOSIZIONE

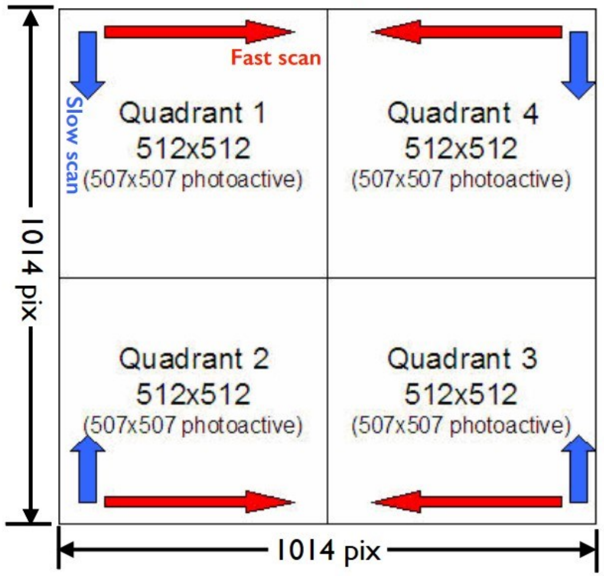
NIRCAM VS WFC3

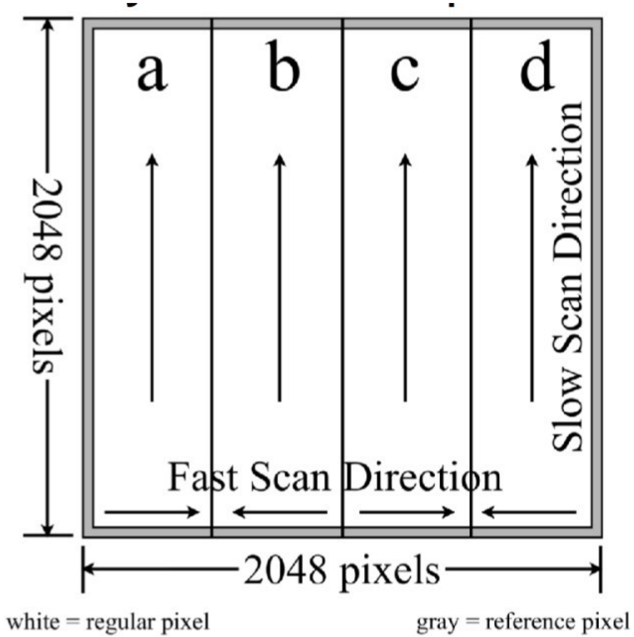
SIMILITUDINI:

- STESSA **ARCHITETTURA BASE** (tecnologia HgCdTe)
- STESSO **PRODUTTORE** (Teledyne Technologies)

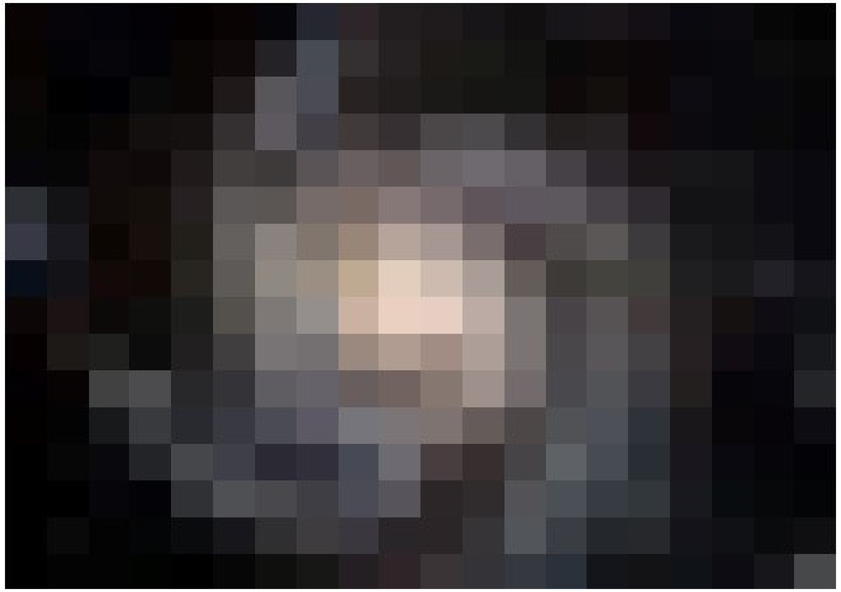
DIFFERENZE:

- DIVERSO **ARRANGIAMENTO PIXEL** ("quadranti" per WFC3 vs "striscie" per NIRCam) => **meno pixel sprecati**
- DIVERSA **RISOLUZIONE ANGOLARE** (NIRCam > WFC3) => immagini **più dettagliate**





NIRCAM VS WFC3: RISOLUZIONE



Simulazione di una galassia distante come vista dall'Hubble grazie al WFC3 (sinistra) vs Webb (destra)

TDRSS:

Tracking and Data Relay Satellite System

9 satelliti (3 operativi, 6 di riserva)

+

ground stations

ANTENNE:

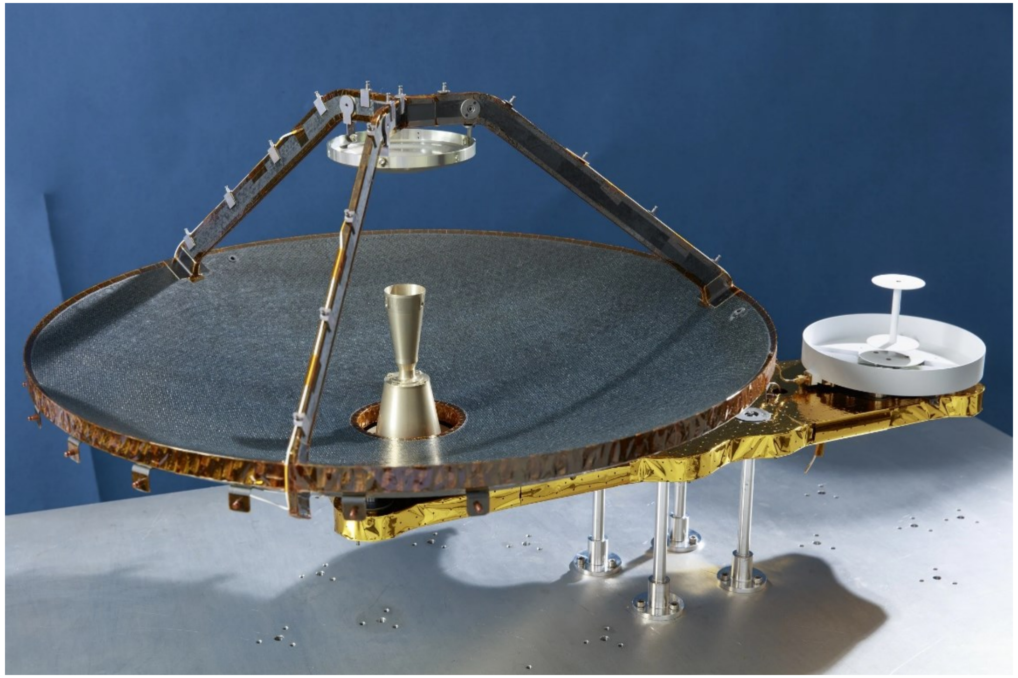
- **FORWARD e AFT LOW GAIN ANTENNA (LGA):** telemetria (0.5/4/32 kbps) e comando (0.125/1 kbps)
- **HIGH GAIN ANTENNA (HGA)** telemetria (0.5/4/32 kbps) e data (1.024 Mbps)

RECORDING:

- **2 reel-to-reel TAPE RECORDERS** 1 Gbits/registratore
- **1 SOLID STATE RECORDER (SSR)** 12 Gbits

ANTENNE montate sulla **HGA PLATFORM:**

- 0.2 m **MEDIUM GAIN ANTENNA (MGA):**
  S-band; command uplink, low rate telemetry downlink, ranging (40 kbps)
- 0.6 m **HIGH GAIN ANTENNA (HGA):**
  Ka-band; telemetry, high rate data downlink (0.875/1.75/3.5 Mbytes/s)

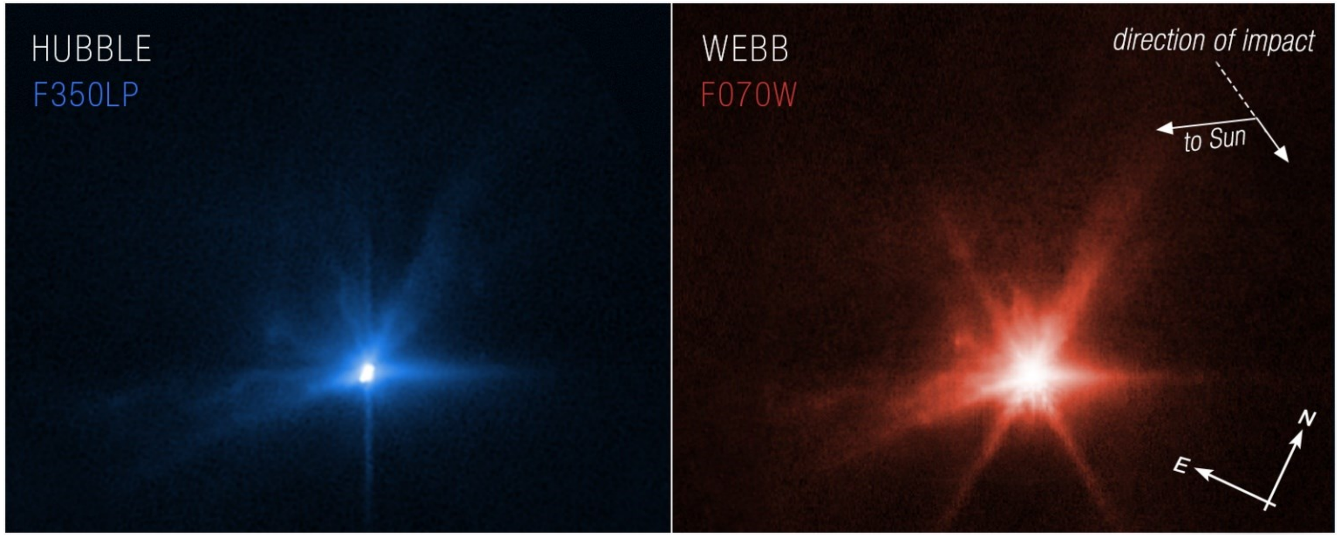


RECORDING:

- **1 SOLID STATE RECORDER (SSR):**
  65 Gbytes

HUBBLE E JAMES WEBB LAVORANO IN SIMBIOSI

IL JAMES WEBB NON E' STATO CREATO PER SOSTITUIRE L'HUBBLE!



BIBLIOGRAFIA

- James Webb Space Telescope: Project Overview; IEEE Aerospace and Electronic Systems Magazine (Volume: 22, Issue: 7, July 2007) (https://ieeexplore.ieee.org/document/4285974)
- JWST Observatory Hardware (https://jwst-docs.stsci.edu/jwst-observatory-hardware)
- JWST Observatory Overview (https://jwst-docs.stsci.edu/jwst-observatory-hardware/jwst-observatory-overview)
- The ISIM and Instruments (https://www.jwst.nasa.gov/content/observatory/instruments/index.html)
- JWST Integrated Science Instrument Module (https://jwst-docs.stsci.edu/jwst-observatory-hardware/jwst-integrated-science-instrument-module)
- Instruments: NIRCam (https://www.jwst.nasa.gov/content/observatory/instruments/nircam.html)
- JWST Near Infrared Camera User Documentation (https://jwst-docs.stsci.edu/jwst-near-infrared-camera)
- JWST Communication Subsistem User Documentation (https://jwst-docs.stsci.edu/jwst-observatory-hardware/jwst-spacecraft-bus/jwst-communications-subsystem)
- JWST Data Volume And Data Excess (https://jwst-docs.stsci.edu/jwst-general-support/jwst-data-volume-and-data-excess)
- JWST Solid State Recorder (https://jwst-docs.stsci.edu/jwst-observatory-hardware/jwst-solid-state-recorder)
- Observatory - Communications (https://www.nasa.gov/content/goddard/hubble-space-telescope-communications-system)
- Hubble Space Telescope Servicing Mission 3A: SOLID STATE RECORDER (https://asd.gsfc.nasa.gov/archive/hubble/a_pdf/news/facts/FS15.pdf)
- LESKO, J. (1991). Hubble Space Telescope communications and data handling. 29th Aerospace Sciences Meeting.
- Charles A. Beichman, Marcia Rieke, Daniel Eisenstein, Thomas P. Greene, John Krist, Don McCarthy, Michael Meyer, John Stansberry, "Science opportunities with the near-IR camera (NIRCam) on the James Webb Space Telescope (JWST)," Proc. SPIE 8442, Space Telescopes and Instrumentation 2012: Optical, Infrared, and Millimeter Wave, 84422N (21 September 2012)

BIBLIOGRAFIA

- Bernard J. Rauscher, “Comparing and Contrasting Detectors: JWST NIR vs HST WFC3” (https://ntrs.nasa.gov/citations/20150023398)
- Hubble Fact Sheet (https://esahubble.org/about/general/fact_sheet/)
- WIDE FIELD CAMERA 3 (https://www.stsci.edu/hst/instrumentation/wfc3)
- Hubble's Instruments: WFC3 - Wide Field Camera 3 (https://esahubble.org/about/general/instruments/wfc3/)
- Observatory - Instruments | Wide Field Camera 3 (https://www.nasa.gov/content/observatory-instruments-wide-field-camera-3)
- Observatory – Communications (https://www.nasa.gov/content/goddard/hubble-space-telescope-communications-system)
- Hubble’s Science Instruments (https://hubblesite.org/mission-and-telescope/instruments)
- About - Hubble Servicing Missions | SM3B (https://www.nasa.gov/content/about-hubble-servicing-missions-sm3b)
- Hubble Space Telescope Servicing Mission 3A: SOLID STATE RECORDER (https://asd.gsfc.nasa.gov/archive/hubble/a_pdf/news/facts/FS15.pdf)
- Hubble Facts: Advanced Camera for Surveys (ACS) (https://asd.gsfc.nasa.gov/archive/hubble/a_pdf/news/facts/sm3b/fact_sheet_ACS.pdf)
- Hubble Space Telescope Servicing Mission 4 (https://www.nasa.gov/mission_pages/hubble/servicing/SM4/main/Summary_FS_HTML.html)
- Science Instrument Command and Data Handling Module (https://www.nasa.gov/mission_pages/hubble/servicing/SM4/main/SICDH_FS_HTML.html)
- Observatory – Hubble vs. Webb (https://www.nasa.gov/content/goddard/hubble-vs-webb-on-the-shoulders-of-a-giant)
- WFC3 Instrument Handbook (https://hst-docs.stsci.edu/wfc3ihb)
- Hubble Space Telescope 30th Anniversary Press Package (https://esahubble.org/press/kits/presskit010/)
- M. Williamson, "James Webb, son of Hubble," in Engineering & Technology, vol. 10, no. 4, pp. 66-69, May 2015