On Sept. 28, NASA announced that it was delaying the launch of JWST from October 2018 until sometime between March and June 2019. In that announcement, Thomas Zurbuchen, the head of NASA's Science Mission Directorate, said the delay was "not indicative of hardware or technical performance concerns," but rather that "integration of the various spacecraft elements is taking longer than expected." NASA reported that the project's budget would accommodate the delay.

At the hearing, witnesses suggested that the situation might be somewhat more serious, given that the delay would nearly deplete remaining schedule and budget reserves. Cristina Chaplain, a Government Accountability Office official, said that integration is the "most risky phase" of mission development and that "more delays are possible given the risks associated with the work ahead and the level of schedule reserves that are now below what is recommended." Her written testimony characterized the possibility of further delays as "likely" and indicated that, if that happens, it would cause the mission to breach the cost cap set in 2011.

PICO Integration and Test

- T-4 years:
  - Cryogenic Qualification Model [Subsystem testbeds, Industry]
  - Device level detector testing [Foundaries, Univ. Labs]
- T-3 years:
  - Full focal plane testing/calib (sub-K cryo/detectors/mux) [Large dedicated testbed, 5 mo]
  - Cryogenic photogrammetry of telescope and truss [Large 300-40K chamber, 1 mo]
- T-2 years:
  - Full payload integration (receiver+cooler+telescope+spacecraft)
- T-1 year: Full Payload Thermal/Vacuum [Very large, instrumented, env chamber, 2 mo]
- T-0: Launch

PICO Integration and Test

- T-4 years:
  - Cryogenic Qualification Model [Subsystem testbeds, Industry]
    - 6 K cooler
    - 2 K cooler
    - 100mK ADR

PICO Integration and Test

- T-4 years:
  - Cryogenic Qualification Model [Subsystem testbeds, Industry]
  - Device level detector screening/characterization [Foundries, Univ. Labs]
    - T_C , R_N , P_{SAT} , yield, optical efficiency & spectral response

PICO Integration and Test

- T-4 years:
  - Cryogenic Qualification Model [Subsystem testbeds, Industry]
  - Device level detector testing [Foundaries, Univ. Labs]
- T-3 years:
  - Full focal plane testing/calib (sub-K cryo/detectors/mux) [Large dedicated testbed, 5 mo]
    - Integration of the flight cooler and full FPU (focal plane unit)
    - Cryogenic characterization
    - Noise, stability with representative optical load.
      - Requires careful design of the load to provide appropriate background for each band
      - Need to be able to inject periodic (dipole+galactic) amplitude signal to assess system noise, responsivity and linearity. This will require 3mK fluctuations on a 3K load for bands ≤ 350 GHz and a ~20K grey-body above.
    - Polarimetric calibration
    - Spectroscopic calibration
    - This will require a minimum of two runs, each with several (2-4?) weeks of cold testing

PICO Integration and Test

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  - Full focal plane testing/calib (sub-K cryo/detectors/mux) [Large dedicated testbed, 5 mo]
  - Cryogenic photogrammetry of telescope and truss [Large 300-40K chamber, 1 mo]
    - Requires full optical assembly and truss
    - Measurement of cold emissivity?

PICO Integration and Test

- T-4 years:
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  - Device level detector testing [Foundaries, Univ. Labs]
- T-3 years:
  - Full focal plane testing/calib (sub-K cryo/detectors/mux) [Large dedicated testbed, 5 mo]
  - Cryogenic photogrammetry of telescope and truss [Large 300-40K chamber, 1 mo]
- T-2 years:
  - Full payload integration (receiver+cooler+telescope+spacecraft)
- T-1 year: Full Payload Thermal/Vacuum [Very large, instrumented, cryo chamber, 2 mo]
  - Only full up testing of cryo chain, including passive cooling
  - Long thermal time constants require a long run
  - Only opportunity to test system end-to-end through cold optics
    - Constrain parasitic optical loading from the instrument (req. sophisticated cold load)
    - Noise testing, RFI (Telemetry, spacecraft bus), microphonics

Planck Integration and Test
(HFI centric)

- June-September 2005: Cryogenic Qualification Model (individual subsystem level)
- June 2005 - Feb 2006: Device level testing [Caltech and Cardiff] (quick turnaround)
- March 2006: HFI integration and test of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (4 days testing / 28 day turnaround)
- May 2006: cryogenic video photogrammetry of telescope and truss [300-40K]
- June-July 2006: HFI testing and calib of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (20d testing / 42 day turnaround)
- 2007: full integration (telescope+HFI+LFI+cooler+spacecraft)
- May-August 2008: Thermal/Vacuum [CSL Focal 5, Liege] (~few days)
- May 2009: Launch

https://authors.library.caltech.edu/20758/1/Pajot2010p11790Astron_Astrophys.pdf

Planck Integration and Test
(HFI centric)

- June-September 2005: Cryogenic Qualification Model (individual subsystem level)
  - Testing of cooler subsystems (20K, 4K, dilutor)

Planck Integration and Test
(HFI centric)

- June-September 2005: Cryogenic Qualification Model (individual subsystem level)
- June 2005 - Feb 2006: Device level testing [Caltech and Cardiff] (quick turnaround)
  - Dark device characterization
  - Optical efficiency, spectroscopy, polarimetric calibration of the 2K feeds & detector sub-assemblies
  - In truth, it is difficult to draw a clean line between detector development and device level I&T. The detector development work (SWBs and PSBs) began much earlier – late 90's for the SWBs and early 2000's for the PSBs.

Planck Integration and Test
(HFI centric)

- June-September 2005: Cryogenic Qualification Model (individual subsystem level)
- June 2005 - Feb 2006: Device level testing [Caltech and Cardiff] (quick turnaround)
- March 2006: HFI integration and test of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (4 days testing / 28 day turnaround)
  - Cryogenic functionality
  - Basic functionality of detectors/readout
  - Test of calibration hardware

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- March 2006: HFI integration and test of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (4 days testing / 28 day turnaround)
- May 2006: cryogenic video photogrammetry of telescope and truss [300-40K]
  - Thermo/optical/mechanical validation of telescope and mechanical structure
  - A very limited amount of optical testing

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- March 2006: HFI integration and test of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (4 days testing / 28 day turnaround)
- May 2006: cryogenic video photogrammetry of telescope and truss [300-40K]
- June-July 2006: HFI testing and calib of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (20d testing / 42 day turnaround)
  - Calibration run: spectroscopic, polarimetric, optical efficiency, cross-talk
  - Only prolonged period of operation of the science instrument under reasonably representative optical loading
  - Not able to test all bands under representative loading
  - NOT LONG ENOUGH – missed phenomenology that would have saved time/science in flight.

Planck Integration and Test
(HFI centric)

- June-September 2005: Cryogenic Qualification Model (individual subsystem level)
- June 2005 - Feb 2006: Device level testing [Caltech and Cardiff] (quick turnaround)
- Feb 2006: Device level testing [Caltech] (quick turnaround, feed-level testing: dark characterization, spectra, optical efficiency, polarimetric cal)
- March 2006: HFI integration and test of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (4 days testing / 28 day turnaround)
- May 2006: cryogenic video photogrammetry of telescope and truss [300-40K]
- June-July 2006: HFI testing and calib of sub-K cooler + focal plane [Saturne cryostat, IAS Orsay] (20d testing / 42 day turnaround)
- 2007: full integration (telescope+FHFI+LFI+cooler+spacecraft)
- May-August 2008: Thermal/Vacuum [CSL Focal 5, Liege] (~two weeks)
  - Provision for a ~4K load was an afterthought. Implementation did not allow for meaningful testing of the receiver (load stability, temperature, etc did not allow for representative noise testing, crosstalk with LFI, parasitic loading, etc)