TITAN SCIENCE WITH THE JAMES WEBB SPACE TELESCOPE. C. A. Nixon[1], R.K. Achterberg[2], M. Ádámkovics[3], B. Bézard[4], G. L. Bjoraker[1], T. Cornet[5], A. G. Hayes[6], E. Lellouch[4], M. T. Lemmon[7], S. Rodriguez[8], C. Sotin[9], N. A. Teanby[10], E. P. Turtle[11], R. A. West[9], [1]NASA Goddard Space Flight Center, Planetary Systems Laboratory, Greenbelt, MD 20771, USA, conor.a.nixon@nasa.gov, [2]Department of Astronomy, University of Maryland, MD 20742, USA, [3]Astronomy Department, University of California at Berkeley, Berkeley, CA 94720, [4] Observatoire de Paris-Meudon, LESIA (Bât. 18), 5, place Jules Janssen, 92195 Meudon Cedex, France, [5]ESA European Space Astronomy Centre (ESAC), PO BOX 78, 28961, Villanueva de la Cañada (Madrid), Spain, [6]Department of Astronomy, Cornell University, Ithaca, NY 14853, USA, [7]Department of Atmospheric Sciences, Texas A&M University, MS 3150, College Station, Texas 77843, USA, [8]Laboratoire Astrophysique, Instrumentation et Modélisation (AIM), CNRS-UMR 7158, Université Paris-Diderot, CEA-Saclay, 91191 Gif sur Yvette, France, [9]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109, USA, [10]School of Earth Sciences, University of Bristol, Wills Memorial Building, Queen's Road, Bristol BS8 1RJ, UK, [11]Johns Hopkins University Applied Physics Laboratory, Laurel, MD 20723, USA.

Introduction: In January 2014 the Solar System Working Group (SSWG) for the James Webb Space Telescope (JWST) chartered ten science focus groups (SFGs) to examine the potential science applications of the observatory for various solar system targets. We present a summary of the findings of the Titan SFG, organized into five thematic areas: (1) Titan surface; (2) tropospheric clouds; (3) composition of the lower atmosphere; (4) composition of the middle atmosphere; (5) stratospheric hazes and clouds. Our investigation considered such issues as: Titan observability; spatial resolution available and required for various science investigations; spectral resolution, signal-to-noise ratio and saturation times for various observing modes of NIRSpec, NIRCam and MIRI. We discuss the strengths and weaknesses of JWST for the proposed observations, including the need for sub-arraying and high spectral resolution to avoid saturation. We conclude that JWST will be a prominent player in the cadre of current and forthcoming major observatories that can study Titan, including Cassini, ALMA, SOFIA and next-generation optical telescopes.

Themes: An overview of the thematic results follows:

Surface: Titan's crust is probably composed primarily of water ice, but known from Cassini to be covered in many places by liquid or solid organic depositions from the atmosphere. Examples include the northern seas, composed of methane, ethane and other $H_xC_yN_z$ species; and the equatorial dune fields, which are thought to be solid organic materials; plus other terrains of unknown composition. JWST can significantly contribute to our understanding of the surface organic composition using NIRSpec to identifiy absorbions such as liquid ethane at 2 μm, while NIRCam will provide mapping context especially for regions of activity/change.

Lower atmosphere clouds: Clouds were first identified on Titan in 1998, and since then there has been near-continuous following of cloud events. Methane saturates in the upper troposphere and rains out on the surface. JWST can play a major role in watching large clouds evolve over a timescale of days to weeks, most likely as a TOO (target of opportunity) observing request in response to a detection by a high cadence, ground-based monitoring campaign. NIRSpec and NIRCam can work in tandem to provide spectral and spatial information on Titan's weather.

Tropospheric gases: In this area the major interest is in measuring the methane relative humidity in the troposphere, which may be spatially varying. Bands in the near-IR can be exploited to map methane vs latitude using NIRSpec, in both CH_4 and isotopologues, which will provide less saturated absorption bands.

Stratospheric gases: Active photochemistry and ion chemistry in Titan's upper atmosphere results in a diverse array of gas species in the stratosphere, which exhibit mid-IR vibrational spectra that have been mapped by Cassini CIRS. These gases act as tracers of atmospheric motion, and vary both vertically, and in latitude and with time. Seasonal changes in these gases can be measured by the MIRI instrument which coverse the range 5-28 μm.

Middle-atmosphere hazes and clouds: Titan exhibits a seasonal reversal of haze opacity between hemispheres at many wavelengths, caused by haze transport towards the winter pole. Imaging with JWST NIRCam will help to constrain dynamical models, while high-resolution (R~2700) spectral imaging with NIRSpec in integral field mode (IFU) at resolutions of ~0.1". Stratospheric ice clouds have also been seen by Cassini, and JWST will be able to discriminate large-scale polar clouds seen in both the north and south.