GPS Occultation Density Observations Associated with the Midnight Temperature Maximum

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13 May 2015

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- GPS Radio Occultation Data (GPSRO)
- MD_pM Observations
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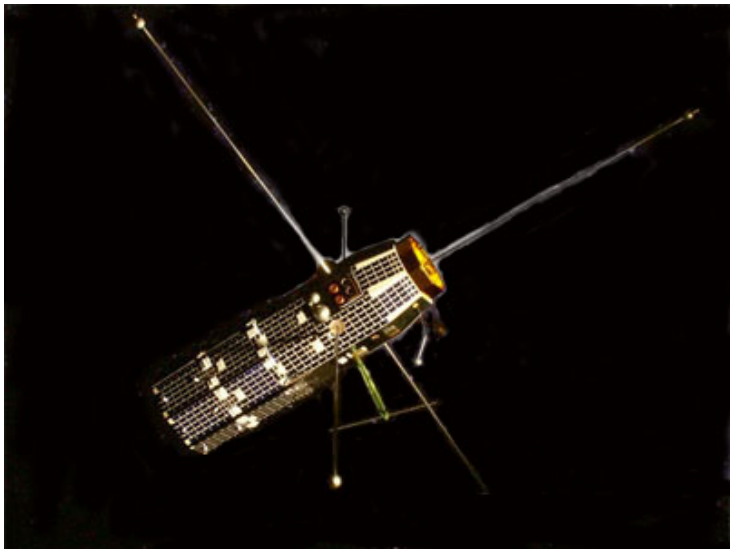
  - *Occurrence Statistics*
- Summary



C/NOFS satellite. [*Courtesy of NASA*]

Nighttime Thermospheric Variations

Midnight Temperature Maximum

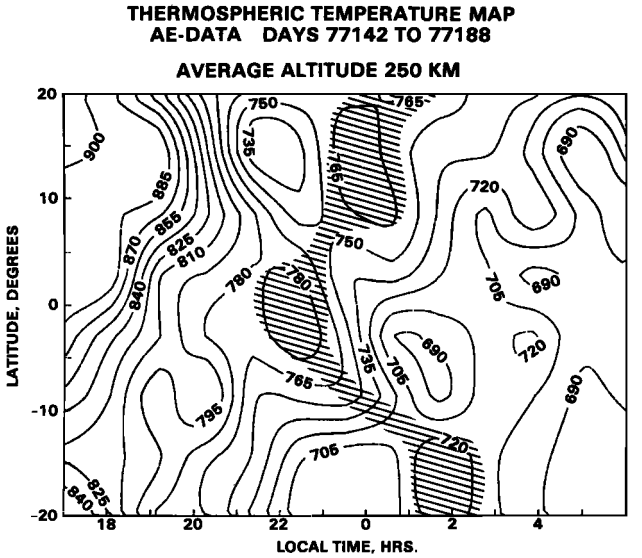


Figure 3. Thermospheric temperature map for the period 77142 to 77188 in the latitude band ±20 deg. and between 1700 and 0600 LT. The shaded contours indicate the midnight temperature maximum distribution.

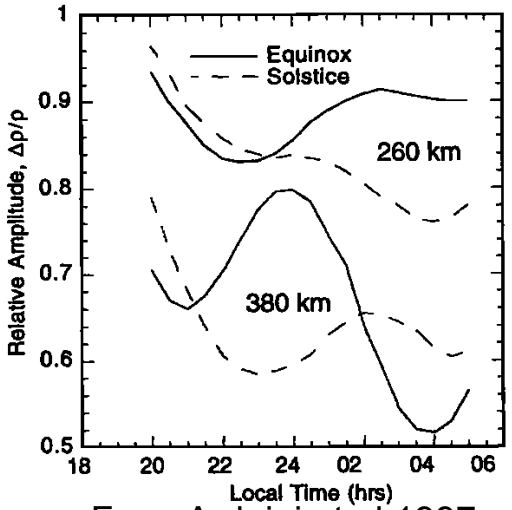
From Herrero and Spencer, 1982

- The Midnight Temperature Maximum (MTM) is enhancement in thermospheric temperature [see reviews: Herrero et al., 1993, Colerico and Mendillo, 2002]
  - *Occurrence between 2200 and 0300 LT*
  - *Latitude Range: +/- 20°*
  - *Temperature Range: ~25 to 170K [Meriwether et al., 2011]*
  - *Observed by ground-based all-sky, photometers, Fabry-Perot Interferometers and on-orbit sensors.*
  - *Early observations from ground photometers*
  - *First on-orbit observation by Neutral Atmosphere Temperature Instrument (NATE) on Atmospheric Explorer-E satellite*

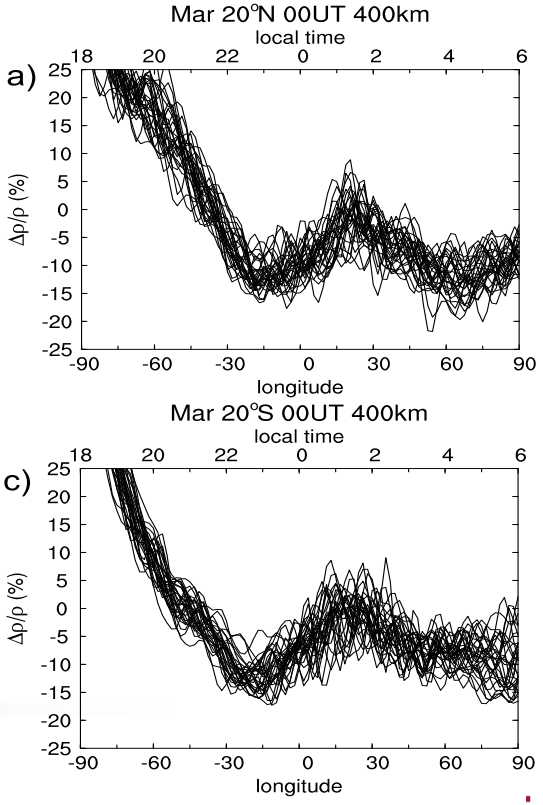
Nighttime Thermospheric Variations

Midnight Density Maximum (MDM)

- Midnight Density Maximum (MDM)
  - *Occurs over similar latitudes*
  - *Typically lags MTM*
- On-orbit observations:
  - *Mass spectrometers*
  - *Drag measurements*
    - Observed by San Marco III and V [*Arduini et al.*, 1996]
- Phenomenon produced in models/simulations:
  - *Whole Atmosphere Model* [*Akmaev et al.*, 2010]
- Produced by tidal winds at equator
  - Downward progression of MTM/MDM indicative of upward propagating tidal meridional wind



From Arduini et al.1997



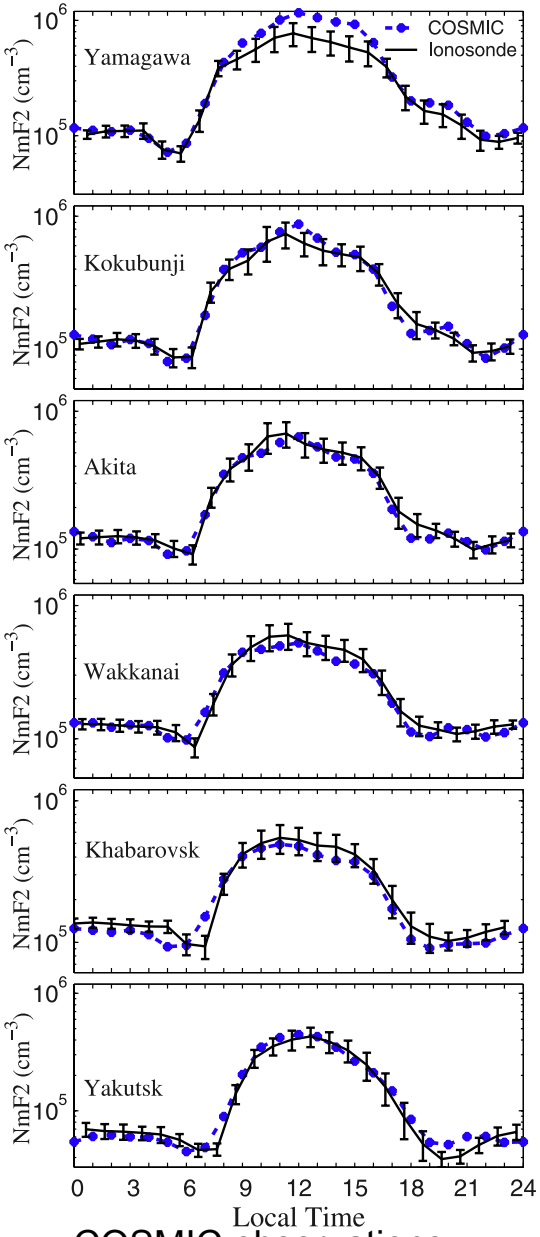
From Akmaev et al. 2010

Nighttime Ionospheric Variations

Midnight Plasma Density Maximum (MD_PM)

- Plasma density enhancements in nighttime NmF2 have been observed by ionosondes, GPS, radars [e.g. Farelo et al., 2002, Luan et al., 2008]

- Theories for MD_PM formation focus on transport via theremosphere/ionosphere coupling
  - *Downward flux of electron density several hours following earlier upward **ExB drift***
  - *Meridional winds associated with MTM transport plasma to higher altitudes.*



COSMIC observations compared to ionosonde data. [From Luan et al. 2008]

Communication/Navigation Outage Forecast System

C/NOFS Satellite

- Joint DoD Space Test Program and Air Force Research Laboratory (AFRL)
- Original Purpose: “Demonstrate a technique for locating and forecasting scintillation in the low latitude ionosphere”.
- Payload:
  - *Vector Electric Field Instrument (VEFI): NASA Goddard*
  - *Coherent Electromagnetic Radio Tomography (CERTO) NRL*
  - *GPS Sensor (CORISS): The Aerospace Corporation*
  - *Neutral Wind Meter and Ion Velocity Meter (CINDI): UT Dallas*
  - *Planar Langmuir Probe (PLP): AFRL*

C/NOFS in testing at General Dynamics
[*Courtesy of AFRL]*

Communication/Navigation Outage Forecast System

C/NOFS Satellite – Cont.

- Launched: 16 April 2008
- Initial Orbit:
  - *405 x 853 km*
  - *13.0 inclination*
  - *97.3 min period*
- Current Orbit altitude:
  - *Approx. 345 x 500 km*
- Re-entry estimate: Fall 2015

Artist Rendition of C/NOFS. Image Credit: NASA/Goddard Space Flight Center

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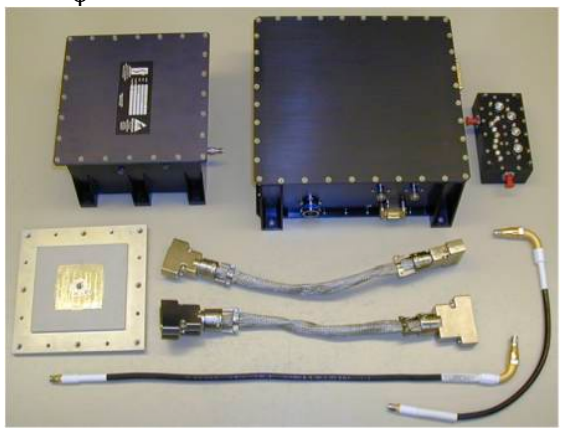
CORISS Overview

C/NOFS Occultation Receiver for Ionospheric Sensing and Specification

- CORISS is a Modified Version of the Jason/ICESat Receiver
  - *RF front end adapted to C/NOFS RFI requirements*
  - *Single patch antenna on anti-velocity side of s/c*
  - *Receiver s/w updated by The Aerospace Corporation to perform occultations & other special functions (Tom Meehan consulting)*
    - On-board processing of scintillation parameters: S4, σ_ϕ, spectra
- Data Collection Modes
  - *LR data (0.1 Hz):*
    - Non-occulting tracks
  - *MR data (1.0 Hz):*
    - Occulting tracks (typically elevations below 0º)
  - *HR data (50 Hz):*
    - Ionospheric altitudes (-5º to ~50 km tangent altitude) **at night** (L1 only)
    - Tropospheric altitudes (below ~50 km tangent altitude



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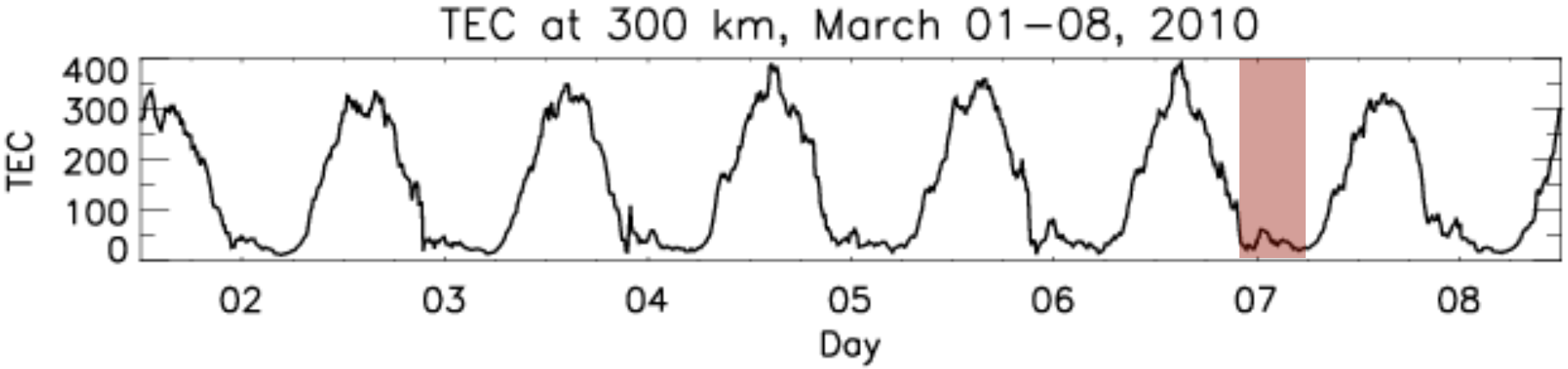
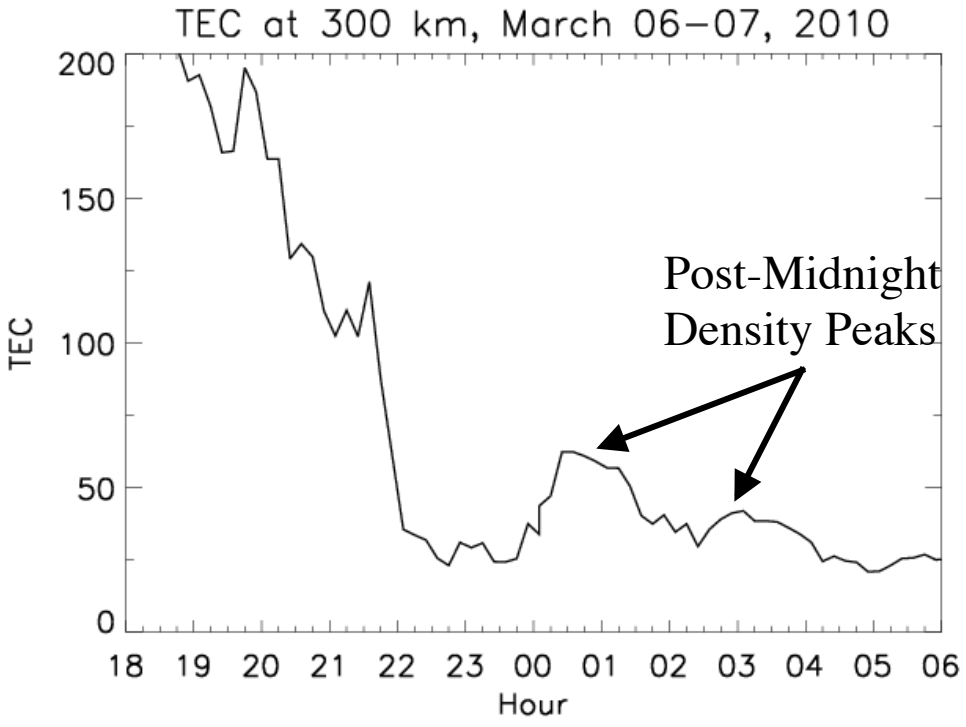
MD_PM Observations

Identifying Density Enhancements



- 300 km reference altitude selected
  - *Near nighttime F-Peak*
- Density enhancements visible 5 out of 7 days in example week.
- March 6-7 observed 2 enhancements ~130 min apart.



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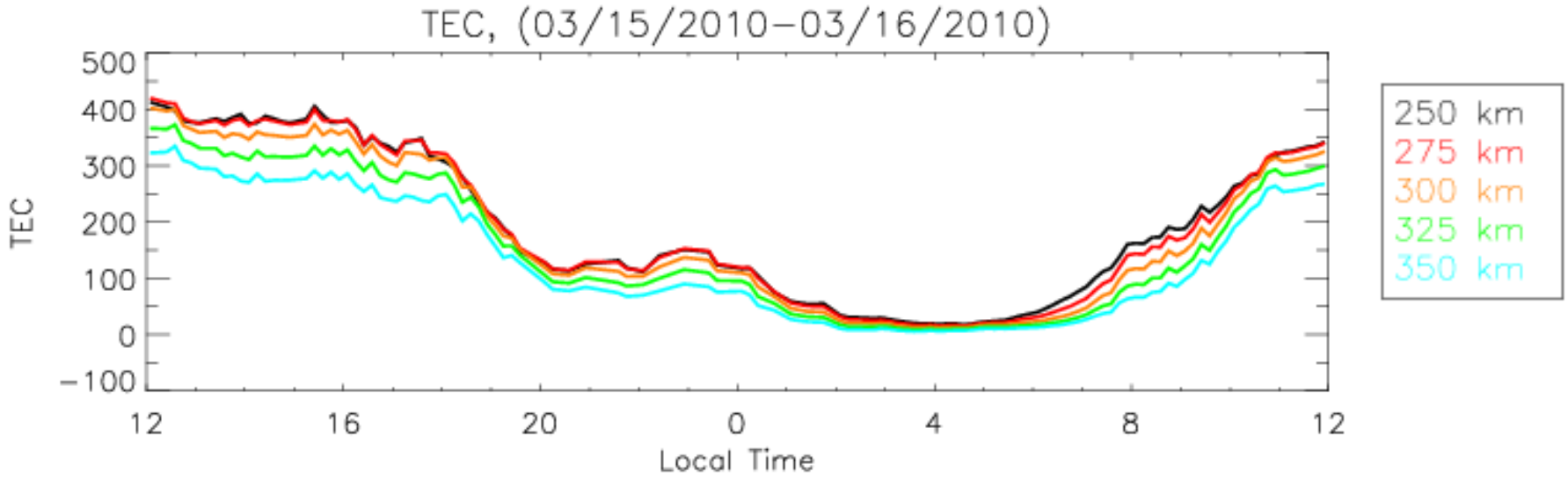
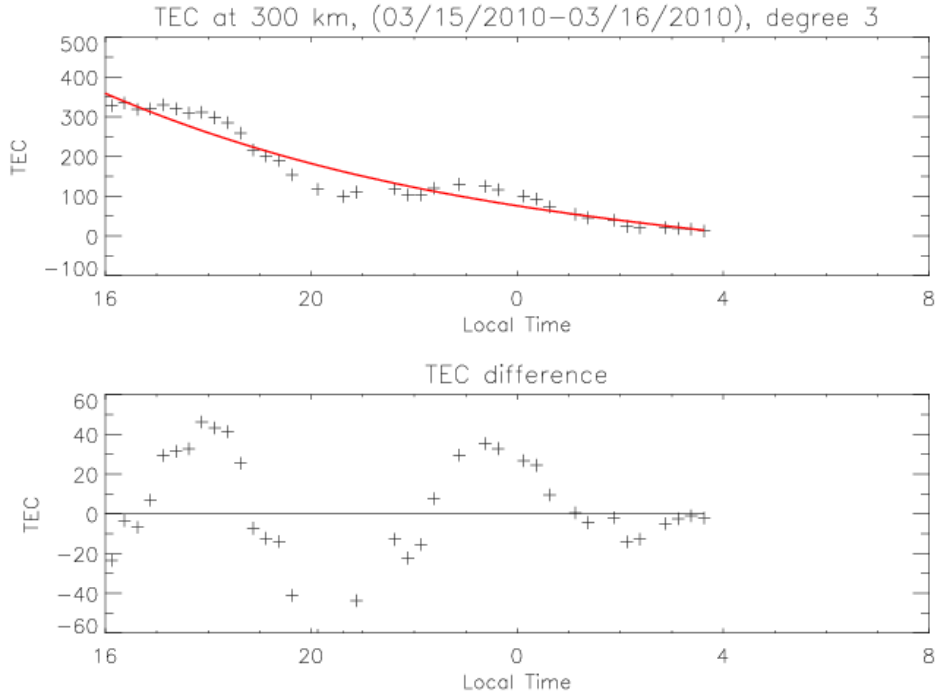
Density Enhancement Due to F-peak motion?

- F-Peak between 250 and 275 km most of the night
- All altitude slices exhibit similar density enhancement
  - *Local F-peak motion unlikely source.*
- Shows a “wave-like” structure



Temporal Variations of Nighttime Ionosphere Density

- Typical MD_PM has changes in TEC >40 TECU but may be as low as 10 TECU
- Polynomial fit to 8 hours preceding nighttime minimum and then subtracted from data
- Multiple enhancements commonly observed
- GPSRO spans large horizontal area (lat/lon)
  - *Multiple peaks may be due to latitude variations captured.*
- Typical periods of variations: 2, 4, and ~6 hr



Occurrence Statistics

October 2009 - April 2010

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
Days of Data	27	30	29	29	25	27	28	29
Percent Occurrence	81.5	96.7	89.7	93.1	92.0	92.6	92.9	96.6
Average Time of Maximum (LT)	0106	2341	0035	0001	0043	2346	0007	0031
Average Time of First Minimum (LT)	2114	2037	2121	2137	2202	2125	2132	2105

- Valid days include at least one data point every 15 minutes
- Geomagnetically quiet period
  - *Ap < 20 for all but ~10 days*
- Average time is near local midnight
- MDM appears to be relatively common

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Summary

- 6 months of GPS radio occultation data has been analyzed for MDM events
- MDM events are relatively common with an average occurrence rate of 91.9%
- Post-sunset TEC enhancement events occur independent of geomagnetic activity
- A wave structure appears to often exist with periods of 2, 4, ~6 hr.
- The TEC enhancements occur primarily on the bottom-side of the F-peak, but are observable for the dataset's entire altitude range.
- There are significant latitudinal and longitudinal variations in MDM magnitude and surrounding depletions

Acknowledgements: This work is supported under The Aerospace Corporation's Sustained Experimentation and Research for Program Applications

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