High Resolution Dynamics Limb Sounder

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Description/Summary/Contents: **Rationale, Planning and Execution**
Keywords:
Purpose of this Document:

Aura HIRDLS Pitch Maneuvers

- **HIRDLS Aura Spacecraft Pitch Maneuvers - Rationale, Planning and Execution.**
  - **This paper will discuss:**
  - **Why we need to perform pitch-down maneuvers;**
  - **How they are planned and executed;**
  - **What data are obtained;**
  - **When are they performed;**
  - **Who uses these data and how do they help the science data?**

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- **Why we need to perform pitch-down maneuvers?**
  - **Before we start. - When the Aura spacecraft pitches down, HIRDLS line of sight turns spaceward and at a sufficient angle of pitch the field of view is filled with space-cold radiation.**
  - **First let's mention that the original (unobscurred telescope) baseline plan was to perform period pitch down maneuvers in order to characterize to angle dependent stray radiation from the scan mirror. For a non-perfect scan mirror - and with the expected increase of contamination on the surface, radiation could enter the channel field of view from far-field regions. This is particularly important for limb scanning views of the Earth since a bright or hot source is at a small angular displacement from the desired channel field of view.**
  - **Thus, as the bright Earth limb is rotated away from the field of regard of the telescope, the radiation detected should be only that due to space and mirror emission. Angular dependent differences can be attributed in large part to scatter/diffuse reflection from the mirror.**

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- **Why we need to perform pitch-down maneuvers?**
  - **However, during launch the telescope entrance aperture became partially blocked by some material, most likely from the contamination enclosure around the fore-optics.**
  - **The material is close to the entrance pupil of the telescope therefore the composite field of view is almost uniformly affected (there is some field angle dependent variation), however the obscuring material contributes a large amount of radiant energy in addition to that from the target atmosphere. Earthshine and backscatter radiation warms the material. This emission varies with time, position in the orbit and season. We need some way of characterizing this emission and subtracting it from the total measured.**
  - **Considering time periods long relative to time of a HIRDLS scan, i.e > 15 seconds, there are coherent spatial and temporal emission patterns that lend themselves to principal component analysis, e.g EOF. For such a method to be predictive three conditions must be met:-**

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- **How we plan pitch-down maneuvers?**
  - **Condition 1: that the emission patterns are the same when HIRDLS LOS is pitched up (PU) as when in normal orientation (NO).**
  - **Condition 2: that the amplitudes of the chosen components can be determined during individual vertical scans of the atmosphere.**
  - **Condition 3: that the emission patterns are sufficiently stable to be useful.**

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- **How the maneuvers are planned?**
  - **Condition 1: In order that the emission pattern be invariant between PU and NO the radiant loading on the blockage should be the same. This is never quite the case as the aperture necessarily tilts away from the Earth. We need an angle to pitch large enough so that the atmosphere is not seen by any channels at the 'bottom' end of the scan and small enough that the back-loading on the blockage is minimally different. The PCA results are dependent upon the pitch angle, and their applicability to the NO depends on their sensitivity. This has lead to the design of the pitch angles of -2.6 deg and -5.25 deg.**
  - **A related condition is of course that since there is substantial intra and inter-orbit variation of the back-loading (viz. Equator to pole earthshine variation and sun/eclipse differences, etc) we need to have a sufficient number of orbits of measurement. The duration then is a compromise between statistical sample and loss of science for other instruments. This has lead to the design of 2 to 4 orbits per measurement.**

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- **How the maneuvers are planned?**
  - **Condition 2: Once the PCA and experiments are complete the choice of the numbers of orthogonal components can be made. Then in NO for a given vertical scan at a given position in the orbit the amplitudes of the components can be determined from the part of the scan that is sufficiently above the atmosphere that we can say the signal is due to the blockage emission only. Some channels near the 'top' of the focal plane are best suited and give most information. This has influenced the choice of scan angle range for the science mode scan pattern.**
  - **The 'over-scanning' to space was always part of the design for operational science mode in order to obtain a 'good' space zero reference signal and to obtain a constraint on the diffuse reflection from the scan mirror.**
  - **We also use this part of the scan, in combination with other measurement and analysis to remove the short period (< 10 S) blockage physical oscillations.**

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- **How the maneuvers are planned?**
  - **Condition 3: The long term (T ~ months) stability of the ensuing pattern of emission from the blockage depends of course of the stability of the blockage material itself - largely that it stays in the same place with the same shape. In addition, the solar heating around the structure which is contributing to the blockage emission varies slowly through the year (as well as rapidly round the orbit) and this is characterized by the solar beta angle to the orbit plane - and thus on how much shading occurs round the structure. These two considerations have lead the team to plan a series of pitched measurements every three months and related to the peaks of beta-angle.**

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- **How the maneuvers are planned?**
  - **The choice of scan patterns we operate during the maneuver influences the number of orbits at pitch and the relative transition times. We wish to include scan patterns during the pitch that are the same as those used for normal science acquisition. In addition we include scans that encompass an increased field of regard over the obstruction to assist in the pattern analysis and in other related studies such as constraining the fractional area un-obstructed.**

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- **How the maneuvers are executed?**
  - **Given all the considerations from the previous discussion, it is clear that the design and utilization of the pitch maneuvers has been evolving over the first year of the mission and with guidance from the FOT.**
  - **After discussion with the science team, the HIRDLS IOT sends a request to the FOT (Bill Guit and Joe Purcell) for an Aura pitch-down for HIRDLS calibration with an outline of the scope and a time frame for execution a month or two ahead of time. The FOT then assesses the feasibility of a given day in the suggested time window and notifies the other Aura IOTs for approval or otherwise.**
  - **If the date is agreed then some number of days in advance of the maneuver the HIRDLS IOT will prepare the MCLs and if necessary test them out before hand. All HIRDLS related activities during the maneuver are carried out by MCL, no ground commands are needed.**

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- **How the maneuvers are executed?**
  - **A CAM is held as arranged by the FOT and final go/no-go announced.**
  - **During the maneuver the HIRDLS IOT sits back and watches the maneuver and the HIRDLS scan patterns transition. Near real-time displays in addition to the windows IST allows the HIRDLS team to se the changes in data as are expected.**
  - **(The pitch maneuvers have a beneficial consequence as they allow us to track the HIRDLS gyro scale factors).**
  - **After completion of the maneuver and the delivery of the level 0 science stream to the HIRDLS computing facilities, the analysis of the radiance signals is performed.**

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- **What Data Are Obtained?**
  - **The data include three dimensional maps (2-space, 1-time) of radiance signals over the field of regard (scan elevation and azimuth) obtained over the different pitch angles and scan patterns.**
  - **These data are used to construct the EOFs for all 21 channels and associated statistics. Comparison is made to previous data sets and various tests are performed to validate the applicability of the functions to both the PU and NO data.**
  - **Please refer to a poster for further enlightenment of some of the methods used and characteristics of the data.**

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- **When have they occurred?**
  - **There have been seven Aura pitch down maneuvers for HIRDLS calibration to-date:**

  - **1: 4th Nov 2004.**
  - **2: 9th Feb 2005**
  - **3: 13th Jul 2005**
  - **4: 3rd Nov 2005**
  - **5: 22nd Feb 2006**
  - **6: 13th April 2006**
  - **7: 10th Jul 2006**
  - **The next is planned for**
  - **8: 3rd Nov 2006**

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- **How do the pitch data help the science data?**
  - **There is no way of telling the difference between infra-red atmospheric emission and blockage emission without the data available from the Aura pitch-down. Only when we do this can we be sure that all the emission measured by the detectors comes from the blockage.**
  - **It is fortunate that the material causing the blockage does not change its shape and position over the time periods we are concerned with. Note that the scan mirror is thought to touch the material very slightly and so cause it to wobble and possibly drag depending on the direction of travel of the scan mirror (‘up’ or ‘down’).**
  - **Although the emission from the kapton does vary around the orbit through heating and cooling - the spatial pattern is repeatable and predictable. This is amenable to PCA and this method allows for substantial correction of the signal to extract the atmospheric signal. Residual error characteristics such as mean and height dependent bias are corrected through validation efforts in much the same way as any similar program.**

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- **In summary**
  - **After very much effort studying the emission from the blockage and understanding its behaviour a strategy has been developed to utilize the data obtained from pitching up the HIRDLS line of sight spaceward so that the atmospheric signal can be extracted from the composite signal when in normal orientation.**
  - **The quality of the HIRDLS science data now achieved would not be possible without the pitch data, and although the original conception before launch was for periodic pitch maneuvers, the importance is greater than it ever was.**
  - **Additional factors assist the retrieval of quality products including the very good stability of the instrument so that other possible problems associated with filter radiometry can be ignored.**
  - **The HIRDLS team is grateful for the support given by the Aura FOT and for the excellent performance to-date of the Aura spacecraft.**