ABI Delivers Significantly Increased Capabilities Over Current Imagers

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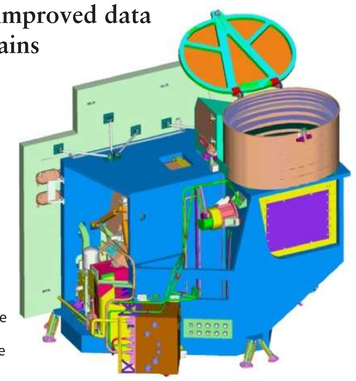
The Advanced Baseline Imager (ABI), designed and built by ITT, represents a significant advancement in performance over the current generation of geostationary Imagers in use by the National Weather Service. Beginning with the GOES R launch in 2012, the ABI will provide scientists and meteorologists with additional and improved data faster than ever before. This poster describes these improvements, explains Scan Modes 3 and 4 (the principal data collection scenarios for ABI), describes ABI's operational flexibility, and quantifies the Level 1B data rates.



1. ABI Requirements

ABI is a mission critical payload on GOES R, providing over 65% of all the mission data products currently defined. The ABI requirements are a significant step up from the current Imager. The cardinal requirements will be discussed in the following subsections.

1.1 Spatial and Spectral Requirements

As shown in Tables 1 and 2, ABI's advanced design will provide users with twice the spatial resolution, six times the coverage rate, and more than three times the number of spectral channels compared to the current GOES Imagers. And it does so with significantly (2.7x) more accurate location of the collected radiance.

Table 1. ABI vs. Imager Requirements

Parameter	Imager	ABI
Resolution (km)	1 & 4	0.5, 1, & 2
Channels	5	16
Full Disk Interval (minutes)	30	5
Data Rate (Mbps)	2.6	66.6
Compression	No	Lossless
Navigation (μrad)	56	21

Table 2: ABI Channel Requirements

Wavelength (μm)			Resolution	SNR	Dynamic Range		Comparable
Center	Min	Max	(km)	NEdT	$mW/m^2/sr/cm^{-1}$	K	Instruments
0.470	0.450	0.490	1	300	14.4		MODIS/MTG/etc.
0.640	0.590	0.690	0.5	300	21.1		GOES Imagers
0.865	0.8455	0.8845	1	300	22.8		MSG/Sounder
1.378	1.3705	1.3855	2	300	21.7		MODIS/MTG/etc.
1.610	1.580	1.640	1	300	20		MSG/Sounder
2.250	2.225	2.275	2	300	12.1		MODIS/MTG/etc.
3.90	3.80	4.00	2	0.1 K		400	GOES Imagers
6.185	5.770	6.600	2	0.1 K		300	GOES Imagers
6.95	6.75	7.15	2	0.1 K		300	MSG/Sounder
7.34	7.24	7.44	2	0.1 K		320	MSG/Sounder
8.50	8.30	8.70	2	0.1 K		330	MSG/Sounder
9.61	9.42	9.80	2	0.1 K		300	MSG/Sounder
10.35	10.10	10.60	2	0.1 K		330	MODIS/MTG/etc.
11.20	10.80	11.60	2	0.1 K		330	GOES Imagers
12.30	11.80	12.80	2	0.1 K		330	GOES Imagers
13.30	13.00	13.60	2	0.3 K		305	GOES Imagers

SNR specified for 100% albedo scene; NEdT specified for 300 K scene

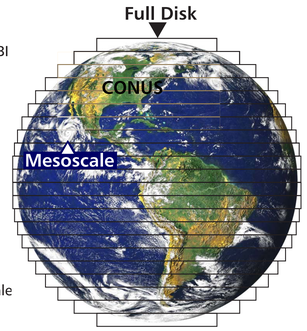
1.2 Data Collection Requirements

There are three scenes defined for the ABI instrument (shown at right):

Full Disk: 17.76 degree circle, which includes the 17.4 degree Earth

CONUS: 4.8129 x 8.0215 degrees (NS x EW)

Mesoscale: 1.6043 x 1.6043 degrees; used for storm watch. Can be located anywhere in the field of regard



Two operational modes have been defined for collecting these scenes. Scan Mode 4 performs full disk collection. Scan Mode 3 is used for storm watches, collecting full disk, CONUS, and mesoscale scenes simultaneously.

The coverage requirements for these scenes are:

Full Disk: Scan Mode 3: Every 15 minutes ± 30 seconds
Scan Mode 4: Every 5 minutes ± 5 seconds

CONUS: Scan Mode 3: Every 5 minutes ± 30 seconds

Mesoscale: Scan Mode 3: Every 30 seconds ± 5 seconds

Both scan modes also include observations required to meet radiometric and INR requirements.

In addition to scene-to-scene interval requirements, there are two data simultaneity requirements to ensure quality images:

- Adjacent North/South pixels across a swath boundary must be collected within 30 seconds of one another.
- Corresponding pixels in all channels must be collected within 5 seconds of one another.

2. ABI Operations

ITT designed the ABI instrument to meet (and often beat) these operational requirements. We leveraged our Imager operational experience but were not constrained by the Imager design. This section addresses those changes, the data collection modes, and the operational flexibility.

2.1 Scene Collection

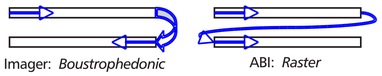
Table 3 summarizes the changes from Imager to ABI in the way that a scene is collected. These changes were made to improve the quality of the collected data.

Table 3: ABI Operations

Parameter	Imager	ABI
Scan Pattern	Boustrophedonic	Raster
Scan Rate (deg/s)	20	1.4
Swaths:		
Full Disk	1384	22
CONUS	374	6
Meso	125	2
Multiple scenes	Interrupt	Interleave

The first change is the scan pattern, as shown in Figure 3 below. The **Imager** uses a **boustrophedonic** ("as the ox plows") pattern. Data is collected while scanning both East *and* West. **ABI** utilizes a **raster** scan pattern. The instrument always collects data while scanning in the same direction (either East *or* West), which yields a constant time delta across the swath boundary.

Figure 3: Imager vs. ABI scan Patterns



Because ABI uses a line array detector, the swath height is considerably larger than the Imager, which means fewer swaths are required to cover a scene. As a result, even though ABI can collect scenes six times faster than the Imager, its scan rate is a factor of 14 slower (1.4 degrees/second rather than 20 degrees/second).

Finally, ABI has the ability to interleave scenes. The Imager is commanded at the scene level. When a new scene is requested, it interrupts the current scene, collects the new one, and then returns to finish the interrupted scene. ABI has the ability to interleave scenes at the swath level, so that multiple scenes can be collected simultaneously at different repeat rates. The advantages of this can be seen in the Scan Mode 3 scenario, discussed in the following section.

2.2 Scan Modes 3 & 4

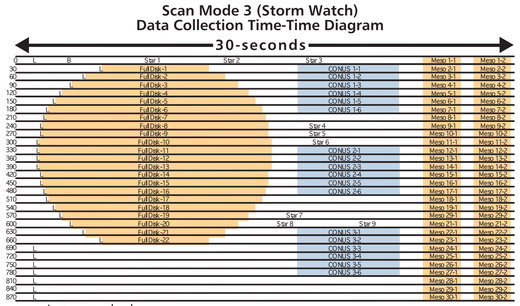
ABI data collection will principally occur in scan modes 4 and 3 (full disk and storm watch, respectively).

Scan Mode 4 collects a blackbody observation, three stars, and a full disk image every five minutes. It will repeat this until commanded otherwise. This delivers all of the data collected by the Imager routine schedule but does it every five minutes. During routine operations it will no longer be necessary to prioritize the frequency with which parts of the full disk are collected.

When a storm watch is required, ABI can smoothly transition to **Scan Mode 3**. Every fifteen minutes Scan Mode 3 collects a blackbody observation, nine stars, one full disk, three CONUS scenes (one every five minutes), and thirty mesoscale regions (one every thirty seconds). This retains the five minute CONUS observations from Mode 4 and adds 30-second storm watches in exchange for a full disk only every fifteen minutes (which is still far more frequent than currently done). No longer will it be necessary to cease collection of full disk or CONUS data in order to do storm watches.

This is possible because of ABI's ability to interleave scenes. This interleaving is shown in Figure 3, a time-time diagram of Scan Mode 3. The time-time diagram takes the 900-second scenario (15 minutes), divides it into thirty 30-second segments, and stacks those vertically. In this way the entire 900 seconds can easily be viewed as a whole.

Scan Mode 3 (Storm Watch)
Data Collection Time-Time Diagram



Some things to notice:

- Scene collections are interleaved at the swath level – a swath of the full disk, a swath of the CONUS, and a complete meso.
- Full disk image is circular, not rectangular.
- Swath-to-swath time intervals are constant for all scenes.
- Mesoscales are 30±0 s apart (much better than the ±5 s allowed by the requirements).
- CONUS scenes are 300±0 s apart.
- Full disk scenes can be 900±0 s apart, since this scenario can be repeated indefinitely.
- For radiometric calibration, a blackbody is collected at the start and a space look is collected every 30 s.
- Three stars are collected every five minutes for INR.

Calibration of channels less than 3 microns (a.k.a. solar calibration) is required infrequently, which is why this is not part of the baseline scan modes.

2.3 Operational Flexibility

ABI is designed to offer great flexibility in on-orbit operations because we recognize that operational needs may change between now and the end of life of ABI. This flexibility includes:

- Scan direction can be West-to-East (default) or East-to-West.
- Space look side can be autonomous sun avoidance (default) or forced to be West or East.
- A limit can be set as to how close to the sun ABI scans. Adjustments in scene collection will occur autonomously based on this scan restriction.
- New scenes and scan scenarios can be defined, even after launch, to facilitate evolving data collection interests over its lifetime. These can be in addition to existing scenes and scan modes, not in place of them.
- Images are independent of the spacecraft orientation. In the event of a yaw flip, scene collection will be adjusted on board so that scan direction is not reversed and scene swaths are still collected North-to-South.

There are many other features that greatly simplify the ground interaction. ABI is not completely autonomous but it is far more so than the current Imager. Ease of operation simplifies the collection of consistent data.

3. Level 1B Data

Downlinked data (Level 0) is decompressed, calibrated, navigated, and resampled (i.e. re-gridded) to form Level 1B pixel images. The advantage of resampling is that all ABI images will be on an identical grid, regardless of variations in spacecraft orbit, attitude, or the mode of the instrument. The users will be able to use the data directly with no post processing.

Note: *the spatial, spectral, and radiometric requirements of ABI are for Level 1B images, so any impacts of calibration, navigation, and resampling have already been taken into account.*

With the increase in information from ABI comes a commensurate increase in data rates and image sizes. Table 4 shows the size of the ABI images for a single channel (see Table 2 for the correlation between channel and resolution) and for the 16-channel image set. In this calculation it is assumed that pixels are stored as 32-bit floating point numbers. It is also assumed that the full disk image, while collected as a circle, will be stored as a square for the convenience of image processing software. It will be up to the ground station contractor, NOAA, and/or NASA to define how these will actually be stored, so actual image sizes could vary.

Table 5 shows the Level 1B data rate for scan modes 3 and 4. These are the average data rates if ABI remains in this particular scan mode.

Table 4: Sizes of ABI Level 1B images (MB)

	0.5 km	1 km	2 km	Image Set
Full Disk (square)	1,961	490	123	4,902
CONUS	240	60	15	600
Meso	16	4	1	40
Scan Mode 3 Image Set	3,161	790	198	7,902
Scan Mode 4 Image Set	1,961	490	123	4,902

Assumption: pixels are stored as 32-bit floating point values

Table 5: Average data rate for ABI Level 1B images

	Average Rate
Scan Mode 3	70.2 Mbps
Scan Mode 4	130.7 Mbps

Based on storing full disk image as a square

4. Conclusion

ABI's advanced design will provide users with twice the spatial resolution, six times the coverage rate, and more than three times the number of spectral channels compared to the current GOES Imagers. The operations flexibility permits consistent collection of Earth scenes, eliminating time gaps in coverage by the need to prioritize some areas over others. These improvements will allow tomorrow's meteorologists and climatologists to significantly improve the accuracy of their products, both in forecasting and nowcasting.

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ABI: At A Glance

Delivers significantly more information than Imager:

- **2x** better spatial resolution
- **6x** more frequent coverage
- **3.2x** more channels
- **2.7x** more accurate location

ABI designed for improved data quality over Imager:

- Slower scan speed **(14x)**
- Raster scan pattern yields uniform line-to-line interval
- Interleaved scenes yields multiple simultaneous scenes

ITT's Scan Mode 3 exceeds requirement:

- Uniform swath-to-swath interval
- Uniform scene-to-scene interval

Scan modes increase data collected:

- ***Routine Operations:*** Entire full disk every 5 minutes
  -No need to prioritize one part over another
- ***Storm Watch:*** Storm watch plus full disk and CONUS
  -15-minute full disk rather than 5-minute

ABI images are user ready:

- Decompressed
- Calibrated
- Navigated
- Resampled

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GOES Advanced Baseline Imager

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