BIT Report on the Svalbard (Longyearbean) summer 2009 flight campaign

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Index

1 BIT FLIGHT Summary

The BIT (Bi-directional Iridium Telemetry) module has flown during the Svalbard campaign 2009 as piggy-back of the SORA main payload. BIT is based on the MSITel module developed by LEN srl in collaboration with IASF-Bologna.

The original task of BIT was to provide:

- full TM/TC link for the SIDERALE payload;
- both h/k and scientific (SIDERALE) data storage (100%) into onboard solid state memory;
- Ground Station operation/service (including Quick-Look of data) in Longyearbean for SIDERALE payload integration and flight.

During the Svalbard 2009 campaign, however, BIT has been charged of additional tasks:

- provide reliable ballast release commands during the flight:
    - This function has been obtained by using one of the six available Secure Digital Output of BIT;
- provide some analog and digital I/O to the main SORA payload;
- provide TM data distribution and Quick-Look of flight h/k data to several Ground Station consoles under request:
    - during the Svalbard campaign the h/k data received by BIT have been distributed to several PCs, were the Ground Station s/w of BIT was installed. In this way several “slave” Ground Stations, up to 32, were able to receive the BIT h/k data both during pre-launch test and the whole flight;
- provide Ground Station operation/service, including Quick-Look of data, from Italy (Len, Chiavari-GE):
    - Due to weather conditions that delayed the launch till July 1st 2009, after IASF-Bologna, LEN and SIDERALE personnel has left Longyearbean, all the above operations were managed by the “main” Ground Station set by LEN in Chiavari (Italy), according to the flight schedule defined with other partners.

All the above tasks were successfully accomplished thanks to the flexibility of the BIT design and to the local (at Longyearbean) support given by IASF-Bologna and LEN personnel during pre-flight phase.
All the data, including some pre-launch test, have been successfully stored into BIT onboard solid state memory and successfully recovered after BIT module came back to Italy on the 14th October 2009.

1.1 *BIT Flight Facts*

The payload was successfully launched on July 1st 2009 at 00:08:23 AM (UT) from the Longyearbean Airport, and reached the float altitude of 39403 mt at 03:56:05 UT.
The flight continued following a regular schedule till July 4th at 09:43:36 UT, when the payload descent sequence began at 72°47’50’,4 N and 82°58’28’,5 W.

The payload landed on July 4th at 10:20:48 UT, 72°42'47'.5 N and 82°23'25',4 W (Pond Inlet-Canada), at ~736 mt a.s.l.
In the Table I is presented a summary of the main facts occurred during the BIT flight:

Event	***Date***	***Time UT*** *(hh:mm:ss)*	***Elapsed Time*** ***(g****:hh:mm:ss)*
Launch operation start (LYR) 78°15'52" N, 15°30'50" E; Quote: ≈30 mt a.s.l.	30/06/2009	20:48:21	**0**:00:00:00
START data acquisition (CF stored)	30/06/2009	20:48:21	**0**:00:00:00
LAUNCH KO (LYR)	01/07/2009	00:08:23	**0**:03:20:12
Float altitude (39403 m) reached at	01/07/2009	03:56:05	**0**:07:01:54
Max altitude 77°25'38" N, 06°53'24" E: Quote: 39794 m a.s.l.	01/07/2009	07:56:38	**0**:11:02:33
START Balloon descent (35721 m)	04/07/2009	09:43:36	**3**:12:49:31
LANDING (P. Inlet-Canada) 72°44'12" N, 82°24'11" W; Quote: ≈736 m a.s.l.	04/07/2009	10:20:48	**3**:13:25:43
LAST Transmitted data	04/07/2009	13:10:59	**3**:16:15:54
STOP SIDERALE cable link	07/07/2009	00:22:30	**7**:03:25:25
LAST valid GPS data (CF stored)	07/07/2009	00:23:01	**7**:03:25:56
LAST useful h/k data (CF stored)	07/07/2009	08:36:23	**7**:11:39:18
LAST valid h/k data (CF stored)	07/07/2009	10:13:11	**7**:13:16:07

Table I. *Summary of BIT flight main facts*

1.1.1 Ballast Commands

During the flight, according to the decision of the ASI team, were sent the following Ballast Tele Commands:

Ballast ON (UT)	*Altitude (m)*	*TC numbers*	*Ballast OFF (UT)*	*Altitude (m)*
3/7/09 - 02:26:26	34166	3×1 min	3/7/09 - 02:31:11	34200
3/7/09 - 02:38:25	34248	2x1 min	3/7/09 - 02:40:56	34317
4/7/09 - 09:41:16	35654	---	4/07/09 - 13:10:28	744

Table II. *Ballast telecommands during the BIT flight*

1.1.2 BIT Module Recovery

The BIT module has certainly survived to the ground impact (landing) since it continued to send/store TM data for about three days after landing in Pond Inlet (Baffin island, Canada). The following pictures show the BIT conditions after landing.

The BIT aluminum box (Figure 1) clearly shows the effects of fire to which the box has been exposed. Figure 2 shows the TM box, were the BIT module was accommodated as part of the gondola.

In spite of this dramatic landing and post-landing events, all the data stored into BIT solid state memory (Compact Flash-CF) was recovered, decoded, and analyzed. The SIDERALE experiment data recorded on the BIT Compact Flash memory have been decoded and sent by LEN to the SIDERALE P.I. team at INAF/IASF-Milano.

Figure 1. *The SORA gondola after the landing on the 15th July 2009 (9h:24':13''). The crashed envelope of the Telemetry box (with the light blue sticker on) containing the BIT unit is visible on the top side.*

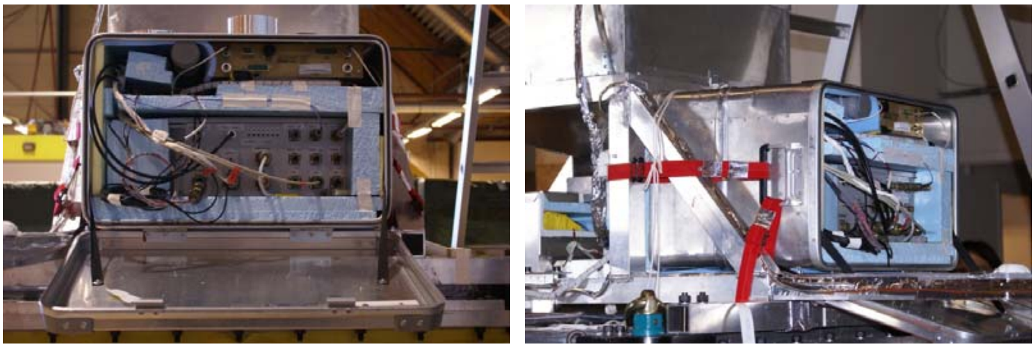

Figure 2. *The Telemetry box with the BIT unit inside in the integration room at Longyearbean (Svalbard Island) airport.*

2 BIT Pre-Launch setup and operations

BIT has been brought by IASF-Bologna and LEN personnel to Longyerbean, where they arrived on June 1st 2009. Setup operations took few hours and BIT was ready for pre-launch integration and test starting from June 2nd. The Ground Station h/w setup has required just to put one Iridium antenna outside the office building, just on the top of a 8 m high boom. A ten meter coaxial cable provided connection between the antenna and the Iridium modem inside the office. A "master" laptop PC running the Ground Station s/w has been connected by RS232 to the Iridium modem. The "master" PC was also connected to the LAN provided by the ASI/ARR team. In parallel, one more "slave" laptop PC provided more extended display of TM(TC data. Through the LAN/Internet connection several "slave" PC were set to receive, display and store the real time received BIT Telemetry data, according to requests by other partners (ASI, ARR, SO.RA., SIDERALE).

During pre-launch test phase, it was possible to set a real time session with the "19th ESA Symposium on European Rocket and Balloon Programmes and Related Research", where the IASF-Bologna and LEN have set an exposition room.

The BIT aluminum box was mounted inside a larger Telemetry box, together with the ASI telemetry (IRIASI) and to the BIT battery power supply package, which has been provided by ASI (see Fig. 3). The TM box was mounted into the gondola as shown in Fig. 3.

Due to weather conditions the launch was delayed till June 30, beyond the date allowed by the BIT team budget, so that it was necessary to move the BIT Ground Station to Italy. That was done since June 15th. The “main” Ground Station was operative c/o LEN in Chiavari (GE-Italy). Other “slave” Ground Station were operative in Italy (Milano, Bologna, Pesaro, Roma) in order to follow the flight in real time.

In practice the pre-launch and the flight phases was managed from Italy, by interacting with ASI team at Longyearbean through Skype and telephone link.

During pre-launch operations and test, as mentioned above, according with ASI team BIT has been connected to the ballast motor by using one of the six “secure digital output” available on the module. This allowed to activate the ballast motor by discrete commands, 1 minute each, to avoid the risk of unwanted ballast release in case Iridium link interruptions. This ballast command has been tested several time before launch and performed perfectly.

Figure 3. *The Telemetry box accommodation on the SO.RA. experiment gondola.*

Similarly, other BIT available I/O were used to send/receive signals from/to the SO.RA. payload. Such interface with SO.RA. payload was easily set and tested and worked properly during flight.

3 The FLIGHT data

The whole flight was monitored continuously by the Ground Station operators (LEN) as well as by the scientific team of BIT and SIDERALE (IASF-Bologna, IASF-Milano). Up to 32 “slave” Ground Station were active to allow other team (ASI, SO.RA.) personnel to monitor h/k from BIT. That was possible by using the h/k data package distributed by LEN to all people who have requested it. An example of the screen views available for h/k data Quick Look is shown in Figure 4.

The TM link was maintained during the whole descent and valid data were transmitted till July 4th at 13:10:59 UT. Figures 5 and 6 shows the behavior of some h/k data **received** by the BIT Ground Station(s). All the plotted data were received in **real time** by the BIT remote ground station in LEN (Chiavari, Italy), with the exception of Sun Elevation in Figure 7 which has been obtained off line and plotted for analysis purposes.

The BIT module performed very well during the whole flight even though the module internal temperature reached the max value of 64.7 °C.

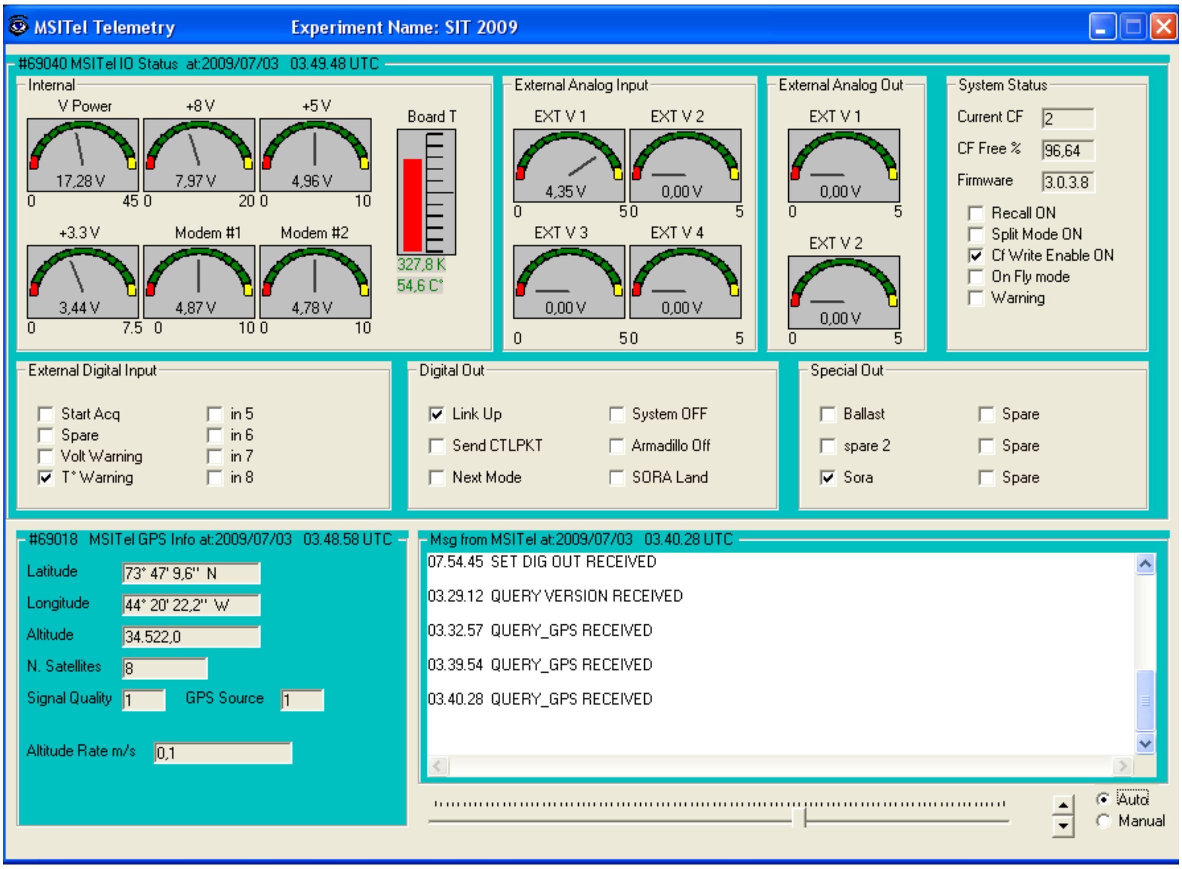

Figure 4. *Example of the BIT Ground Station screen view of house-keeping data*

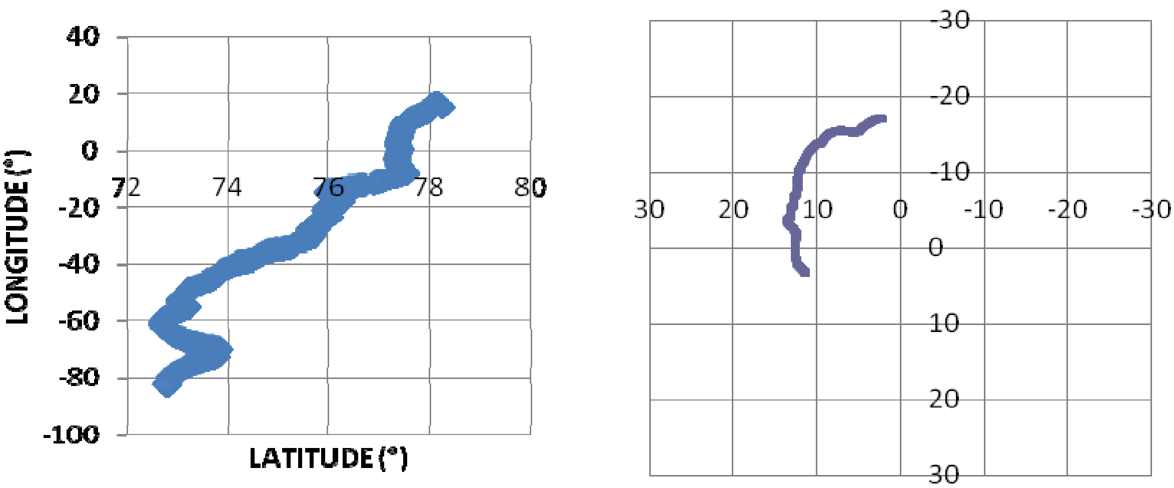

Figure 5. *GPS H/K data related to the balloon trajectory.*

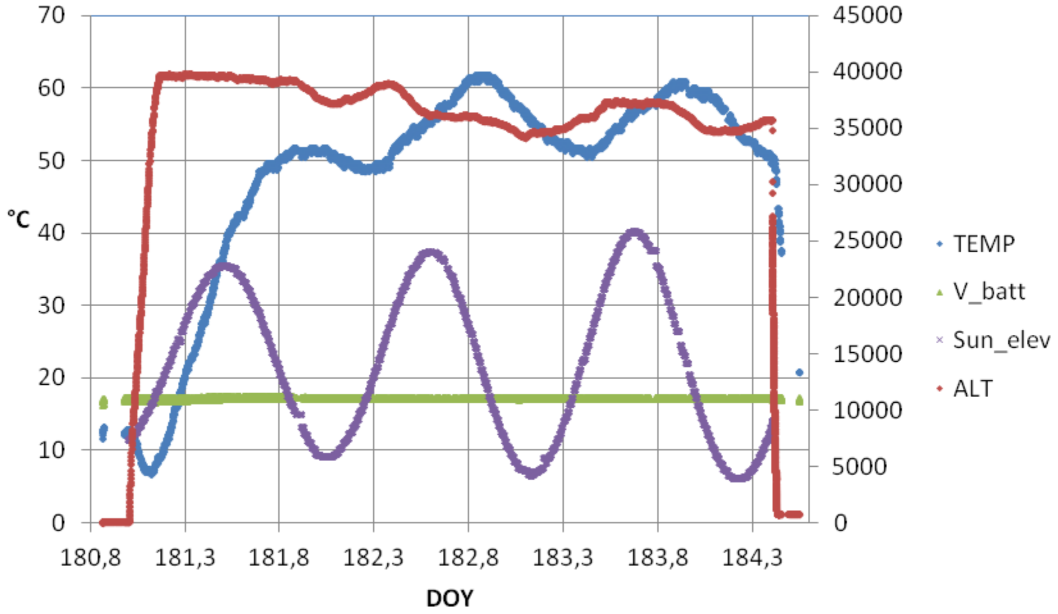

Figure 6. *Environmental and electric parameters behavior from H/K data received at Ground in real time from the BIT unit form the launch to the landing . The Sun elevation has been evaluated off line and superimposed to the H/K data to help in finding correlation with the temperature profile.*

4 POST FLIGHT (after landing) data

The last flight data sent to the Ground Station were on July 4th at 13:10:59 UT. After that the TM link was stopped by the BIT operator. However, the TM link (Iridium) was still active, even though discontinuously, till July 7th at 00:23:01 UT. At that time was also CF stored the last valid GPS data: 72°42'48" N and 08°23'19".5 W.

After the ground impact (July 4th at 10:20:48 UT) the BIT module continued to perform internal CF storage of data till July 7th 2009 at 08:36:33 UT, when the power supply (battery) voltage became as low as 7.33 VDC

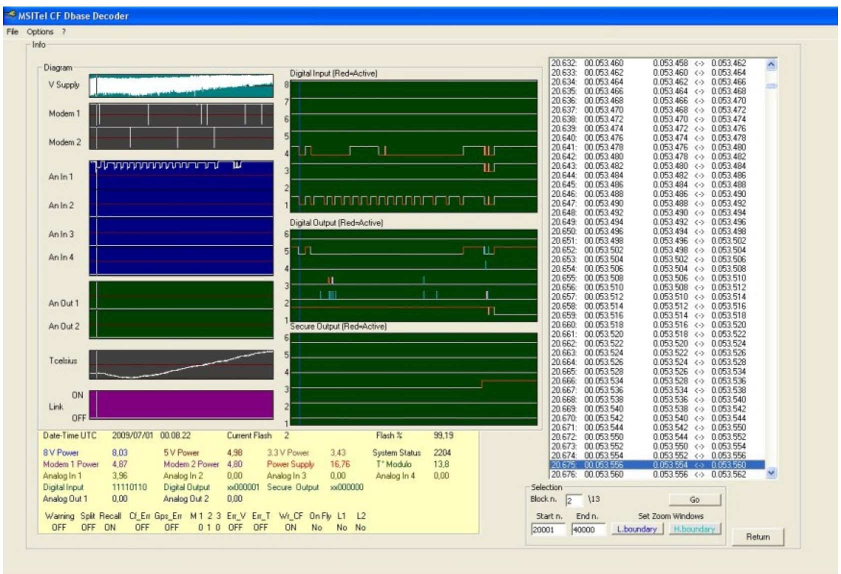

Figure 7. *The display of the Compact Flash decoded data of the first part of flight (white line and data corresponds to the flight KO).*

At about 00:22:20 of July 7th 2009 (DOY 187.0155) something happened to break definitely the link between BIT and SIDERALE (see the red marks in Figures).

The CF stored data have been decoded as soon as the BIT box came back to home (Italy) by using the dedicated s/f package developed by LEN srl. In that way all the data acquired (from re-launch

to post landing phase) by the BIT module have been successfully recovered and available for analysis.
The MSITel decoding s/w is able to generate ".txt" data files that can be used as input for any data analysis/plotting tool. Moreover, the decoding s/w package allows the user to display the data for a Quick Look of them.

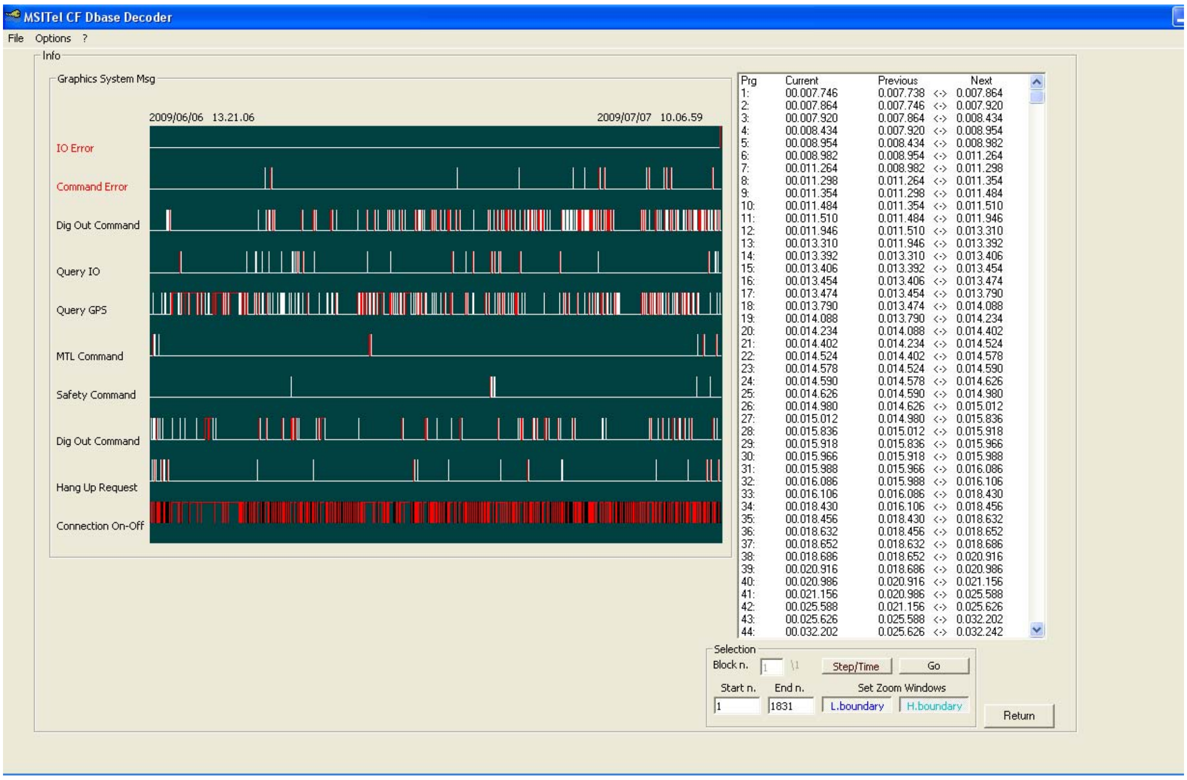

Figure 8. *The display of CF decoded data of the whole flight data (System Messages).*

Examples of the data that can be displayed by the MSITel decoding current s/w tool is shown in Figures 8, 9 and 10.

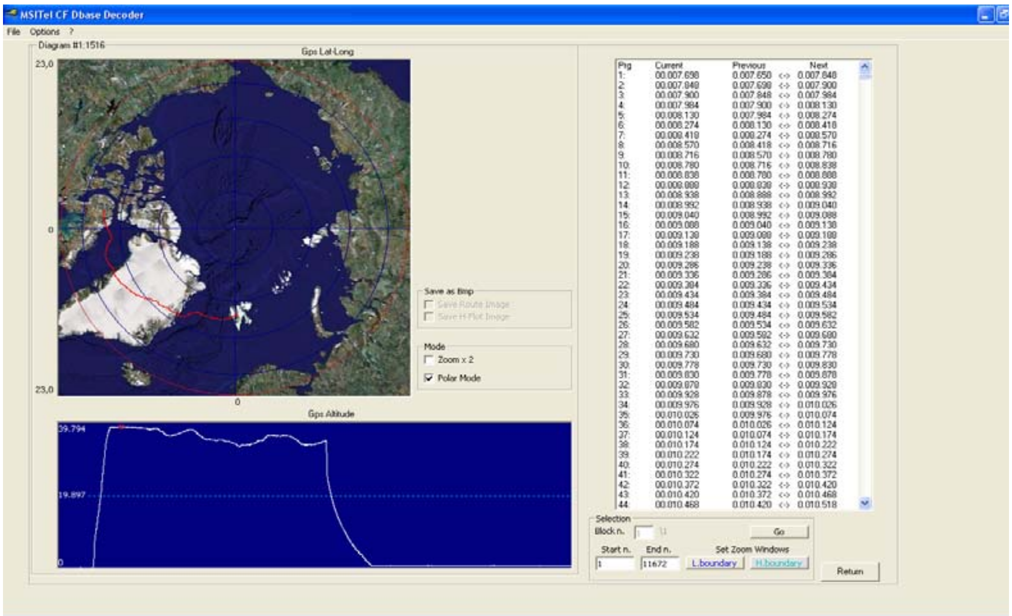

Figure 9. *The display of CF decoded data of the whole flight GPS data.*

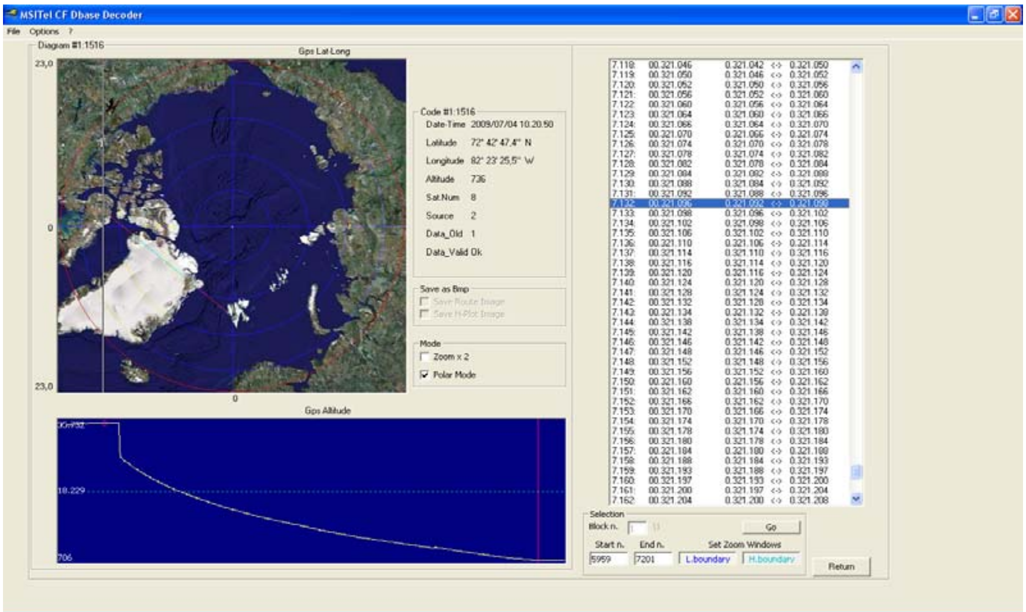

Figure 10. *The display of CF decoded data in the descent window (white line and data are at landing).*

The plots of some house-keeping data acquired after the payload landing (DOY 184,43) are shown in Figures 11, 12, 13, 14, 15.

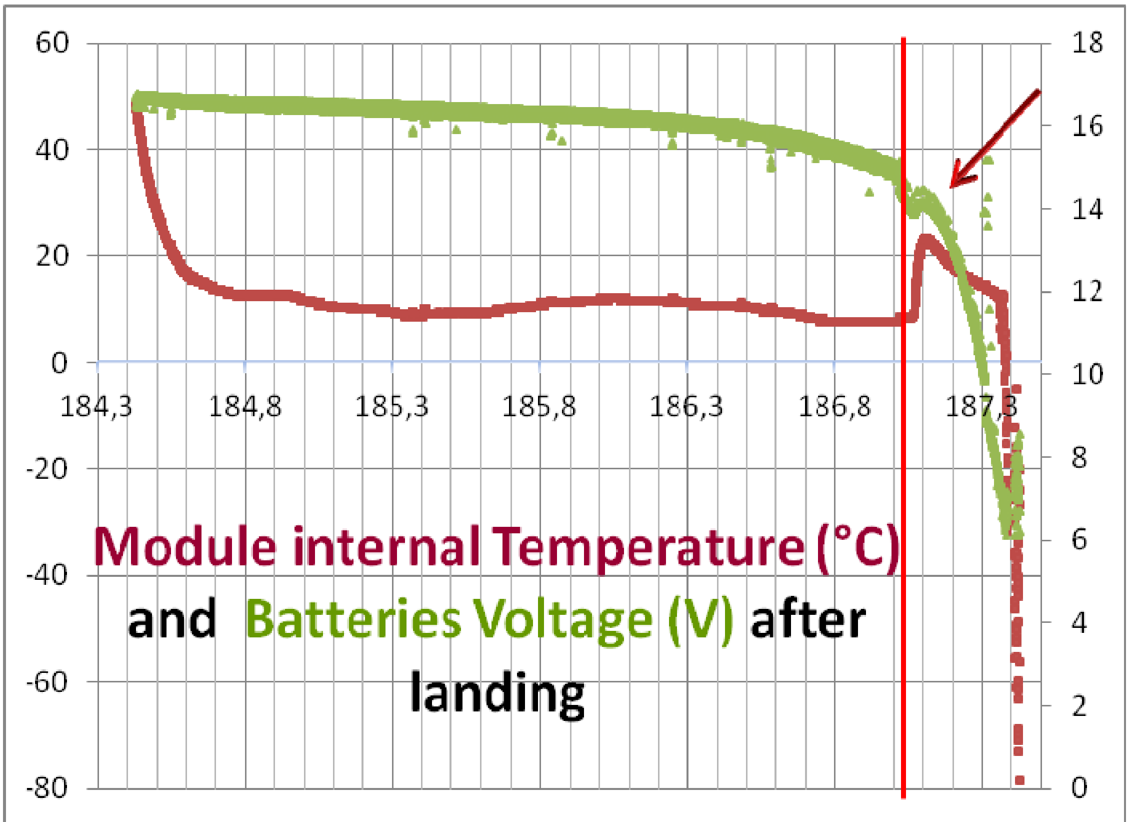

Figure 11. *After landing (DOY 184,43) data; DOY=184 corresponds to July 4th 00:00:00.*

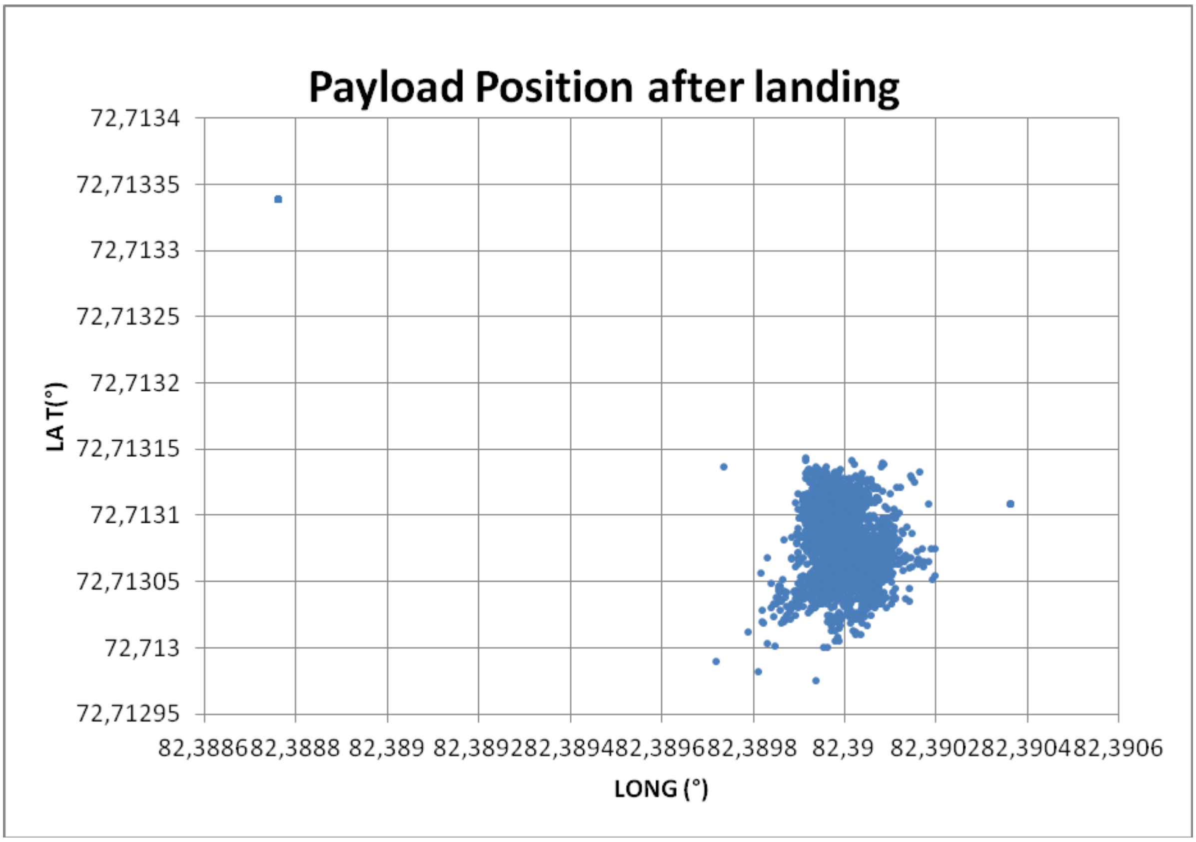

Figure 12. *After landing (DOY 184,43) data.*

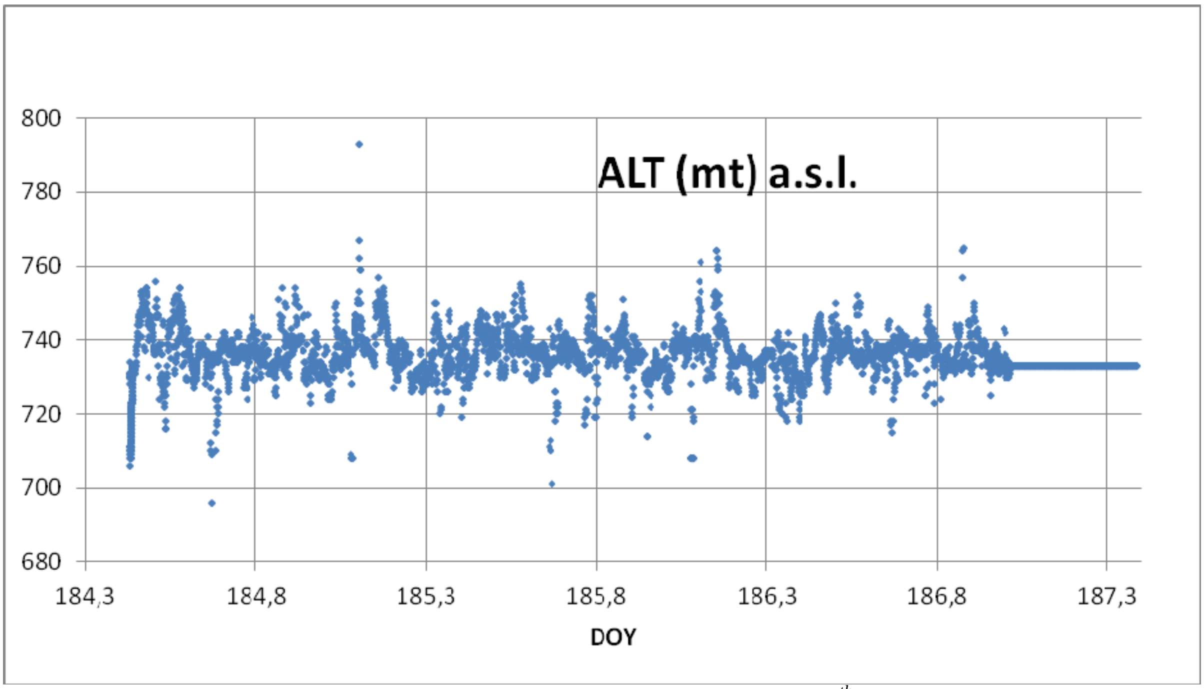

Figure 13. *After landing (DOY 184,43) data; DOY=184 corresponds to July 4th 00:00:00.*

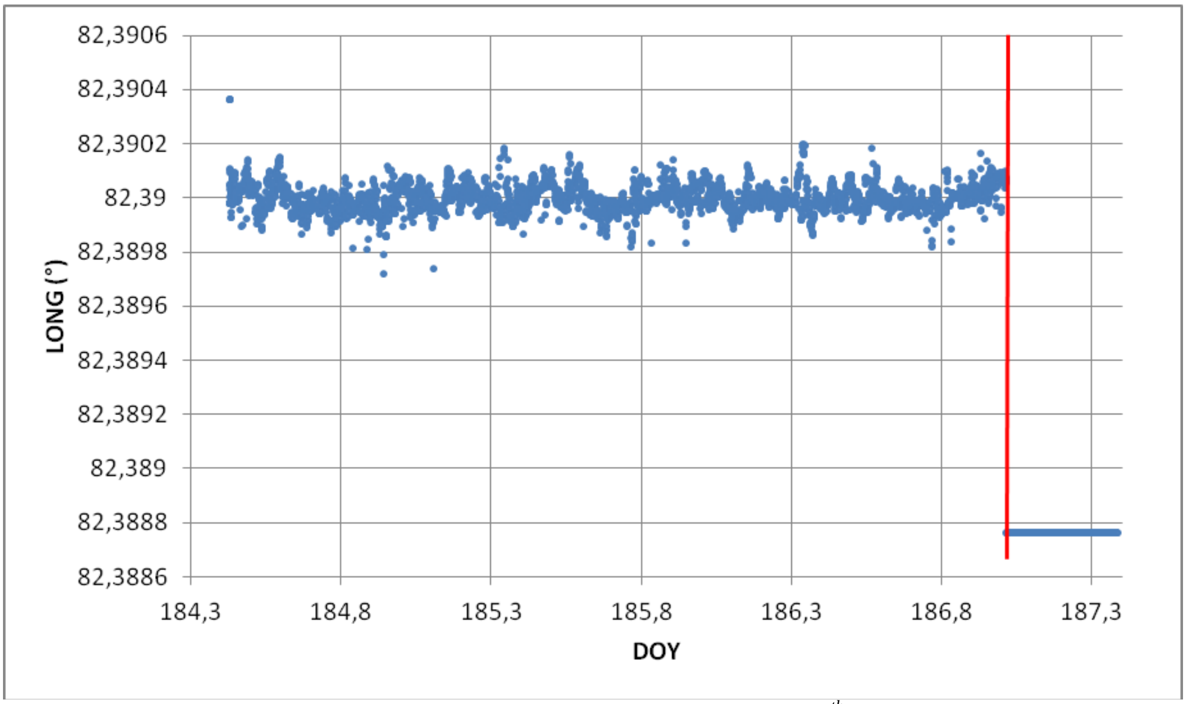

Figure 14. *After landing (DOY 184,43) data; DOY=184 corresponds to July 4th 00:00:00.*

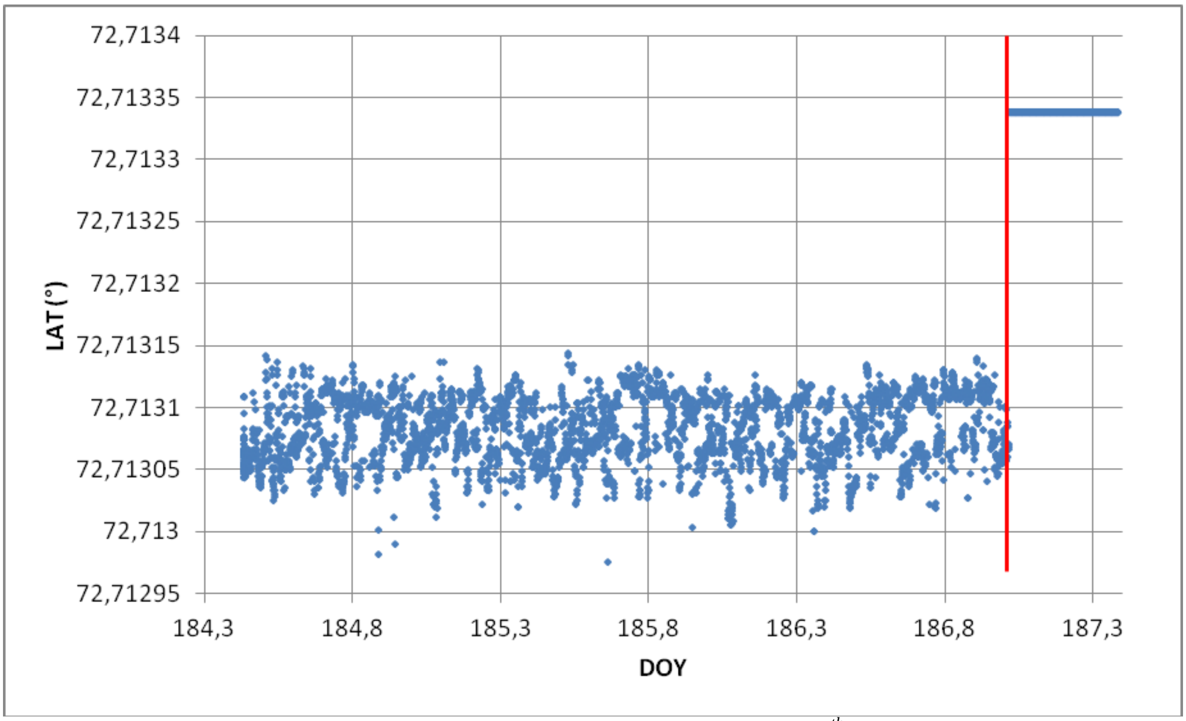

Figure 15. *After landing (DOY 184,43) data; DOY=184 corresponds to July 4th 00:00:00.*

5 BIT Data Analysis

During the flight (from KO to landing) a total of 75757 complete set of h/k data were received at the BIT main Ground Station in Chiavari (GE) as they were sent from the BIT flight module. In the same period the complete set of h/k data stored into the onboard CF memory stick were 124357. Then 61% of data were correctly transmitted/received to/from the main Ground Station and distributed to several (up to 32) slave linked and authorized Ground Stations.

This result takes into account all the link interruptions whatever the cause:

- Hang-up by Ground Station operator commands;
- Iridium link interruptions (unwanted).

5.1 *Analysis of the flight data*

The whole flight was monitored continuously by the Ground Station operators (LEN) as well as by the scientific team of BIT and SIDERALE (IASF Bologna, IASF Milano). Up to 32 “slave” Ground Station were active to allow other team (ASI, So.Ra.) personnel to monitor h/k from BIT. That was possible by using the s/w package distributed by LEN to all the people who requested it. The TM link was maintained during the whole descent and valid data were transmitted till July 4th at 13:10:59 UT.

The CF stored data have been decoded as soon as the BIT box came back to Italy by using the dedicated s/w package developed by LEN srl. In that way all the data acquired (from pre-launch to post landing phase) by the BIT module have been successfully recovered and available for analysis.

The BIT decoding s/w is able to generate “.txt” data files that can be easily used as input for any data analysis/plotting tool. Moreover, the decoding s/w package allows the user to display the data for a Quick Look of them.

5.2 *Analysis of the post-landing data*

The last flight data sent to the Ground Station were on July 4th at 13:10:59 UT. After that the TM link was stopped by the BIT operator. However, the TM link (Iridium) was still active, even though discontinuously, till July 7th at 00:23:01 UT. At that time the last valid GPS data (72°42’48” N and 08°23’19”.5 W) were also stored in the CF.

After the ground impact (July 4th at 10:20:48 UT) the BIT module continued to perform internal CF storage of data till July 7th 2009 at 08:36:33 UT, when the power supply (battery) voltage became as low as 7.33 VDC. The gondola landed on a mild slope but heavily stony as can be seen from Figure 1 where it is possible to see also remaining of the parachute still attached. The GPS positions date plotted in Figure 12-13 demonstrate that the payload has been dragged by wind on the soil.

At about 00:22:20 UT of July 7th 2009 (DOY 187.0155) something happened to break definitely the link between BIT and SIDERALE (see the red lines in Figure 11, 14 and 15). This accident could be probably associated to the explosion of the battery pack, whose results was visible in Figure1.

6 Conclusions

The Svalbard 2009 flight has definitely qualified BIT as the most reliable (low bit rate) telemetry system for circumpolar stratospheric balloon flights. BIT has demonstrated full

capabilities to control even “complex” payload through its several analog and digital I/O and balloon security commands.
The recent agreement between Sweden and Russia allows circumpolar balloon flights from ESRANGE facilities in Kiruna giving to the scientists a real opportunity to access space with lower costs and shorter time schedules. In this perspective BIT represents reference to satisfy the present requirements, even though the development activity is still in progress. Next telemetry modules would have capabilities to send even pictures from the payload while a new s/w package (under test) has been developed to improve user interface and post-flight analysis.