Technical document

Flight Data Recovery Working Group Report

Bureau d'Enquêtes et d'Analyses
pour la sécurité de l'aviation civile
Ministère de l'écologie, de l'énergie, du développement durable et de la mer, en charge des technologies vertes et des négociations sur le climat

Foreword

The conclusions of this document are based upon work performed by the flight data recovery working group. The use of this report for any purpose other than for the prevention of future accidents could lead to erroneous interpretations.

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1 – INTRODUCTION

1.1 Background

On 1 June 2009, Air France flight AF447, an Airbus A330-200 registered F-GZCP, disappeared over the ocean while flying en route between Rio de Janeiro (Brazil) and Paris-Charles de Gaulle (France). Two undersea search campaigns have already been undertaken to locate the wreckage over a vast area of the Atlantic Ocean. Floating debris was recovered and identified on 6 June 2009. Between 10 June and 10 July 2009, a variety of acoustic detection means were deployed to try to localize the aircraft's Underwater Locator Beacons (ULB). From 27 July to 17 August 2009, another search team endeavoured to locate the wreckage by using side scan sonar imagery and a Remotely Operated Vehicle (ROV). Despite these efforts, the search for the wreckage and the flight recorders has not been successful so far. A third phase is currently being prepared for February 2010.

The difficulties encountered have raised questions about the adequacy of existing flight data recovery technology, when considering accidents over oceanic or remote areas.

On 30 June 2009 an Airbus A310 registered 7O-ADJ, operated by Yemen Airways, which was flying the route between Sanaa (Yemen) and Moroni (Comoros), crashed into the sea while on approach to Moroni airport. The two ULBs were detected and localized but were separated from the crash protected memory modules of the flight recorders. It took eight days for the ROV to recover the crash protected memory modules, at a depth of approximately 1200 m.

There have been other examples of extremely costly long lasting searches for wreckage and recorders, such as the crash of the Boeing B747 operated by South African Airways on 28 November 1987.

The causes of the AF447 accident remain unknown. Finding the wreckage and learning more about the contributory factors represents an exceptional challenge for the BEA and the whole international aviation community.

1.2 Objective of the working group

Following the AF447 occurrence as well as other difficult sea recovery operations, the BEA decided to create an international working group called "Flight Data Recovery" in order to look into new technology to safeguard flight data and/or to facilitate the localization and recovery of on-board recorders. Areas such as flight data transmission via satellite as well as new flight recorder or ULB technology have been considered. It was also important to assess the cost and benefits of the possible solutions compared with existing systems. This working group met twice to perform this task.

Within the framework of the investigation into the accident of AF447, the BEA has issued recommendations based on data gathered from these working group meetings.

The results are also included in a European working paper, which will be presented at the next ICAO high level safety conference scheduled in March 2010. France proposed that the subject be placed on the conference agenda.

1.3 Approach

The first BEA's meeting notification proposed exploring solutions in the three following areas:

- Flight data transmission
- New flight recorder technology
- Wreckage localization technology

For each area, a list of possible solutions was established during the first meeting. Only technical feasibility studies were carried out for each solution. Encryption and protection of data, as well as privacy rights, were not addressed at all during the two meetings.

The level of input expected from the group is summarized below.

- Propose solutions to enhance the recovery of flight data after an accident
- Assess the technical feasibility of each solution
- Present the advantages and disadvantages of each solution
- Present the maturity as well as the cost of the solution
- Identify the near, medium or longer term of the solution

The solutions proposed by the group allowed BEA to:

- Perform a cost/benefit analysis of the solutions
- Recommend several options

The objective of the first meeting was to assign the feasibility studies to the various group members and to get answers from each participants supported by presentations and/or technical documents during the second meeting.

The cost/benefit analysis consisted of evaluating the benefits that each solution could have had on the past recovery events identified in a list provided by the BEA (see appendix 1). The cost aspects are derived from the feasibility studies.

1.4 Timeframe

The first meeting took place in the BEA facilities on 14 and 15 October 2009. The second one was in ICAO headquarters on 16, 17 and 18 November 2009. In the second AF447 interim report dated 17 December 2009, the BEA has issued recommendations based on the results of the Flight Data Recovery working group.

1.5 Attendees

The group was composed of more than 120 members from numerous countries, representing a wide range of actors: investigation bodies (BEA, NTSB, AAIB, TSB, BFU…), regulatory authorities (ICAO, EASA, FAA…), airframe manufacturers (Airbus, Boeing), recorder manufacturers (L3Com, Honeywell, GE, DRS, EADS...), ULB manufacturers (Dukane, Benthos), airlines (Air France, Fedex), satellite manufacturers and service providers (Astrium, Inmarsat, iridium, SITA…), international associations (IATA, IFALPA). This allowed the compilation of comprehensive studies on all the items.

2 – WORK PERFORMED

2.1 List of potential solutions

The list of items identified during the first meeting is detailed below. Each item was assigned to at least one group member in order to prepare feasibility studies. These studies were then presented to the group during the second meeting in Montreal.

Item	Assigned to
1 Flight Data Transmission	
1.1 Automatic real time flight data transmission	Inmarsat, Iridium, Astrium
1.2 Triggered transmission of flight data when an upcoming catastrophic event is detected	Inmarsat, Iridium, Astrium
1.3 More extensive use of automatic position reporting (ADS-B)	FAA, Eurocontrol
1.4 Include parameters (position, heading, speed, altitude, accelerations…) in ACARS failure messages	Honeywell, Airbus, Air France
1.5 Include parameters in the AOC ACARS position report messages	Honeywell, Airbus, Air France
1.6 Underwater transmission of data to a vessel when approaching the location of the wreckage	Dukane, Benthos, GE, Honeywell, IXWaves
2 New flight recorder technology	
2.1 Installation of an ED-112 combined deployable and free-floating flight recorder	DRS, GE, Boeing, Airbus
2.2 Installation of a ED-155 combined deployable and free-floating flight recorder	DRS, GE
2.3 Installation of one extra combined ED-155 lightweight flight recorder in the vertical stabilizer	L3Com, Boeing Airbus
2.4 Improve the attachment of the ULB (mandate compliance with EUROCAE ED-112 standard)	Latest version of recorders are already meeting ED-112 spec for beacon attachment
3 Wreckage localisation technology	
3.1 Increased autonomy of ULBs (90 days instead of 30 days)	Dukane, Benthos

3.2 Use of a lower frequency for ULBs, detectable from a greater distance by military ships. These ULBs could either be attached to the aircraft or to the recorder as is done today	Dukane, Benthos, IXWaves
3.3 ULBs transmitting only when interrogated (to improve their autonomy)	Dukane, Benthos
3.4 Deployable ELTs with GPS position broadcasting	DRS
3.5 Other solutions to locate the wreckage from a longer distance (area coverage of 40 nm radius within 30 days after the crash at a maximum depth of 6000 m)	Dukane, Benthos, IXWaves

2.3 Evaluation

2.3.1 Evaluation methodology

The first step of the evaluation consisted in reading each technical and cost answer. The purpose of this activity was to become familiar with the content, gain a sense of the overall solution and approach, and identify any areas that may warrant questions or clarification requests.

Each solution was then evaluated on the following factors and sub-factors:

- Factor 1: Technical feasibility
  - Sub-factor 1.1: Maturity
  - Sub-factor 1.2: Equipage (aircraft/ground station)
- Factor 2: Cost
  - Sub-factor 2.1: Cost per aircraft
  - Sub-factor 2.2: Cost per ground station
- Factor 3 : Applicability to safeguard flight data and/or facilitate recorder localization
  - Sub-factor 3.1: Data recoverability
  - Sub-factor 3.2: Contribution to localization

Each solution was rated against factors and sub-factors (SF), with ranges of numeric scores from 1 to 10. A score of 1 means “unsatisfactory”, and 10 is “excellent”. The overall score for each solution is the weighted average of the scores for each factor. The score for each factor is the weighted average of the score for each sub-factor. The proposed weights are:

Factor	Factor weight	Sub-factor weights within the factor	
Factor 1 Technical feasibility	30%	SF 1.1 SF 1.2	50% 50%
Factor 2 Cost	40%	SF 2.1 SF 2.2	50% 50%
Factor 3 Applicability	30%	SF 3.1 SF 3.2	25% 75%

A coarse evaluation was first performed as a group using red, yellow and green colors during the meeting in Montreal in November. A finer evaluation using numeric scores was performed subsequently by the BEA. The correspondence between the colors and the numeric scores is as follows:

- Red: 1, 2 or 3
- Yellow: 4, 5, 6 or 7
- Green: 8, 9 or 10

Details for evaluating each sub-factor are given below:

SF 1.1: Maturity	If the system is technically mature, part standards are complete and manufacturers currently have approved products for sale, then the score is between 8 and 10. If standards and technology are mature but parts are not approved or are being developed, then the score is between 4 and 7 If system parts and standards have not been developed and/or are not approved, then the score is between 1 and 3
SF 1.2: Equipage (aircraft/ground station)	If aircraft and ground stations are both equipped with the necessary system equipment, then the score is between 8 and 10. If aircraft or ground stations are already partially equipped and/or have some of the necessary equipment, then the score is between 4 and 7. If aircraft or ground stations do not have all the necessary equipment, then the score is between 1 and 3.
SF 2.1 and 2.2 Cost per aircraft and per ground station	If there is little or no cost, then the score is between 8 and 10. If the cost is less than \$10K/aircraft and less than \$25K/ground station, then the score is between 4 and 7. If the cost is greater than \$10K/aircraft or \$25K/ground station, then the score is between 1 and 3.
SF 3.1: Data recoverability	This sub-factor measures how much earlier as well as how much flight data would have been recovered if the solution had been in place for the 26 accidents listed in the underwater recovery operations table provided by the BEA. The score for this sub-factor is computed using the following equation: Score = $\frac{1}{26}\sum_{i=1}^{26} k(i) \times D(i)$, where : ▪ k(i) varies between 0% and 100%, depending how much of the data would have been recovered for accident #i ▪ D(i)=0 if the number of days to recover the recorder(s) of accident #i is less than 5 days ▪ D(i)=5 if this number of days is between 6 and 30. ▪ D(i)=10 if this number of days is greater than 30.
SF 3.2 Contribution to	This sub-factor measures to what extent the solution would have helped in locating the recorder(s) /wreckage area had it been in place

localization	for the 26 accidents listed in underwater recovery operations table provided by the BEA. The score for this sub-factor is computed as follows: Score = $\frac{1}{26}\sum_{i=1}^{26} L(i)$, where : ▪ L(i)=10 if the solution would have helped locate the recorder(s) of accident #i and a ROV had to be used for the recovery ▪ L(i)=5 if the solution would have helped locate the recorder(s) of accident #i and divers recovered the recorder(s), because using divers indicates that the localization of the wreckage was already fairly well determined. ▪ L(i)=0 if the solution would not have helped locate the recorder(s) of accident #i.

2.3.2 Evaluation results

The scores given to each solution are listed in appendix 2 and justified in appendix 3.

The solutions with the highest scores that have a good potential to safeguard data and/or facilitate recorder localization are:

Item #	Description
1.2	Triggered transmission of flight data when an upcoming catastrophic event is detected, but only for aircraft already equipped with SatCom and transmission of a subset of the FDR data (essential parameters or at least latitude, longitude and altitude). However, trigger conditions to define an emergency is not mature yet by industry standards, even though testing has been underway for several years making this approach to streaming data more robust.
1.4 & 1.5	Include parameters (position, heading, speed, altitude, accelerations…) in ACARS messages, but only for aircraft already equipped with ACARS.
2.1	Installation of an ED-112 combined deployable and free-floating flight recorder+ELT, but for new type certificate aircraft only.
3.1	Increased autonomy of ULBs (90 days instead of 30 days)
3.2	Use of a lower frequency for ULBs attached to the aircraft

Items 3.1 and 3.2 have been identified as near-term solutions, items 1.2, 1.4 and 1.5 as mid-term solutions and item 2.1 is for the long term.

3 – CONCLUSION

This working group dedicated itself to reviewing a wide range of solutions in the areas of flight data transmission, new technologies of flight recorders and wreckage localization technology. To do so, the BEA gathered inputs from the industry in order to produce a cost/benefit analysis and identify the best possible ways to safeguard flight data and/or facilitate recorder localization.

The solutions that stem from this evaluation are

- Extended duration of emission of the ULB attached to the flight recorders (90 days instead of 30 days),
- Installation of low frequency ULB (between 8.5 and 9.5 kHz) attached to the plane,
- Regular transmission of basic aircraft parameters (via ACARS for example),
- Triggered transmission of flight data. On this point, additional work is deemed necessary and the BEA will again consult members of the group to conduct a study. And,
- Installation of deployable recorders.

The first two points on ULB are considered near-term solutions, the transmission of triggered data is a medium-term solution and finally the installation of deployable recorders is a long-term solution. On this latter point, the group agreed that it may be difficult to install deployable recorders on planes whose initial design did not take into account the installation of these recorders.

All of these solutions complement each other would contribute to build a robust data recovery solution set.

4 – BEA SAFETY RECOMMENDATIONS

The safety recommendations drawn from the work of the group are issued by the BEA on the day of the publication of the AF447 second interim report on 17 December 2009.

On the basis of this work, le BEA recommends that EASA and ICAO:

1. extend as rapidly as possible to 90 days the regulatory transmission time for ULB's installed on flight recorders on airplanes performing public transport flights over maritime areas;
2. make it mandatory, as rapidly as possible, for airplanes performing public transport flights over maritime areas to be equipped with an additional ULB capable of transmitting on a frequency (for example between 8.5 kHz and 9.5 kHz) and for a duration adapted to the pre-localisation of wreckage;
3. study the possibility of making it mandatory for airplanes performing public transport flights to regularly transmit basic flight parameters (for example position, altitude, speed, heading).

In addition, the BEA recommends that ICAO:

4. ask the FLIRECP (Flight Recorder Panel) group to establish proposals on the conditions for implementing deployable recorders of the Eurocae ED-112 type for airplanes performing public transport flights.

Appendices

Appendix 1: List of past underwater recovery operations

Appendix 2: Evaluation score sheet

Appendix 3: Score justifications

Appendix 1: List of past underwater recovery operations

N°	Aircraft type	Operator	Date	Location	Phase	Depth (m)	# ULB detached	# ULB inop	CVR Days	FDR Days	Means	Cost (M USD)	Floatin g tail	Distance from shoreline (NM)
1	DC9	Itavia #870	27/06/80	Ustica, Italy	En-Route	3500			2555	3650	ROV			
								----------------------------Note :	This large number of days is due to the fact that it was decided to recover the recorders 10 years after the accident. It was not due to technical reasons					
2	B747	Air India #182	23/06/85	Cork, Ireland	En-Route	3250			17	18	ROV		no	
3	IAI 1124 Westwind	Pel-Air Aviation	10/10/85	Sydney, Australia	Climb	92		1 (FDR)	150	150	ROV		no	7
4	B747	South African Airways #295	28/11/87	Mauritius	En-Route	4400			840	Never found	ROV		no	135
5	B757	Birgenair #301	06/02/96	Puerto Plata, Dominican Republic	Take-off	2200			22	22	ROV	1,5		15
6	DC9	ValueJet #592	11/05/96	Everglades, Florida USA	Climb	2	1 (CVR)	1	15	2	Divers	1	no	1
7	B747	TWA #800	17/07/96	New York, USA	Climb	40			7	7	Divers	10	no	8
8	B737	Silk Air #185	19/12/97	Palembang, Indonesia	En-Route	8	2		20	5	Divers		no	0,2
9	MD-11	Swiss Air #111	02/09/98	Halifax, Canada	En-Route	55			9	4	Divers			5
10	B767	Egypt Air #990	31/10/99	Connecticut, USA	En-Route	75	1 (CVR)		13	9	ROV	3,5		60
11	A310	Kenya Airways #430	30/01/00	Abidjan	Take-off	50			26	6	various	0,06	yes	1,5
12	MD-83	Alaska Airlines #261	31/01/00	Los Angeles, USA	En-Route	200			2	3	ROV	2,5		15

13	A320	Gulf Air #72	23/08/00	Muharraq, Bahrain	Approach	3	2		1	1			yes	3
14	MD-82	China Northern #6163	07/05/02	Dalian, China		10			7	14	Divers			
15	B747	China Airlines	25/05/02	Pengu Island, Taiwan	Climb	20			24	25	ROV	12,4	partly	25
16	ATR72	Trans Asia	21/12/02	Pengu Island, Tawan	Descent	60	1 (CVR)		23	22	ROV	2,6	no	14.6
17	B737	Flash Airlines #504	03/01/04	Sharm el-Sheikh, Egypt	En-Route	1030	1 (CVR)		13	12	ROV	1	no	1
18	ATR72	Tuninter	06/08/05	Palermo, Italy	En-Route	1440			23	24	ROV	1	no	
19	A320	Armavia Air #967	02/05/06	Sochi, Russia	Approach	505			20	22	ROV		yes	
20	B737	Adam Air #574	01/01/07	Pare Pare, Indonesia	En-Route	1800			240 ↓	240 ↓	ROV	4	no	
							----------------------------Note :	This large number of days is due to the fact that it was decided to recover the recorders a few months after the accident. It was not due to technical reasons						
21	DHC6	Air Moorea #1121	09/08/07	Moorea, French Polynesia	Approach	670			21		ROV	2	no	
22	Metro III	Charter	09/04/08	Sydney, Australia		100	1 (FDR)		77	77	ROV	0,45	no	10
23	A320	XL Airways	27/11/08	Perpignan, France	Descent	40	1		2	3	Divers	0,5	yes	
24	A320	US Airways #1549	15/01/09	New York, USA	Climb	20			7	7	Divers	0,1	no	0
25	A330	Air France #447	01/06/09	Atlantic ocean	En-Route				Not yet found	Not yet found	ROV	40	yes	
26	A310	Yemenia #626	30/06/09	Moroni, Comoros Islands	Approach	1200	2		60	60	ROV	2,5	no	3

Appendix 2: Evaluation score sheet

Definition of colours and score:

Technical maturity, equipage, cost:

Technical Maturity	8 to 10	If the system is technically mature and the part standards were complete
	4 to 7	If standards and technology are mature but parts are not approved or are being developed
	1 to 3	If system parts and standards have not been developed and/or are not approved
Equipage (Acft/Gnd)	8 to 10	If aircraft and ground stations are both equipped with the necessary system equipment
	4 to 7	If aircraft or ground stations are already partially equipped and/or have some of the necessary equipment
	1 to 3	If aircraft or ground stations do not have all the necessary equipment
Cost	8 to 10	If there is little or no cost
	4 to 7	If the cost is less than $10K/aircraft and less than $25K/ground station
	1 to 3	If the cost is greater than $10K/aircraft or $25K/ground station

Applicability (combination of data recoverability and contribution to localization):

<u>Data recoverability</u>	This sub-factor measures how much earlier as well as how much flight data would have been recovered if the solution had been in place for the 26 accidents listed in the underwater recovery operations table provided by the BEA. The score for this sub-factor is computed using the following equation:

	Score = $\frac{1}{26}\sum_{i=1}^{26} k(i)\times D(i)$, where : ▪ k(i) varies between 0% and 100%, depending how much of the data would have been recovered for accident #i ▪ **D(i)=0** if the number of days to recover the recorder(s) of accident #i is less than 5 days ▪ **D(i)=5** if this number of days is between 6 and 30. ▪ **D(i)=10** if this number of days is greater than 30.
Contribution to localization	This sub-factor measures to what extent the solution would have helped in locating the recorder(s) /wreckage area had it been in place for the 26 accidents listed in underwater recovery operations table provided by the BEA. The score for this sub-factor is computed as follows: Score = $\frac{1}{26}\sum_{i=1}^{26} L(i)$, where : ▪ **L(i)=10** if the solution would have helped locate the recorder(s) of accident #i and a ROV had to be used for the recovery ▪ **L(i)=5** if the solution would have helped locate the recorder(s) of accident #i and divers recovered the recorder(s), because using divers indicates that the localization of the wreckage was already fairly well determined. ▪ **L(i)=0** if the solution would not have helped locate the recorder(s) of accident #i.

	System Feasibility Model	Technical Maturity	Equipage (Acft/Gnd)	Cost	Applicability	Global Score
1	**Flight Data Transmission**					
1.1	**Automatic continuous real time flight data transmission**					
1.1.1	Audio from CVR (Cockpit Area channel 1 track 16kHz, 256 kbit/s)	2	2	1	1	**1.3**
1.1.2	Cockpit images (general cockpit view 4 fr/sec, 2048 kbit/s to 8 Mbit/s)	2	2	1	1	**1.3**
1.1.3	Cockpit images (general cockpit view 4 fr/sec, compressed to 256 kbit/s)	2	2	1	1	**1.3**
1.1.4	All FDR parameters (up to 1024 wps,12.288 kbit/s)					
1.1.4.1	Aircraft not equipped with Satcom	7	2	1	7	**3.85**
1.1.4.2	Aircraft equipped with Satcom	7	6	2	7	**4.85**
1.1.5	Essential parameters (64 wps, 0.768 kbit/s)					
1.1.5.1	Aircraft not equipped with Satcom	7	2	1	6	**3.55**
1.1.5.2	Aircraft equipped with Satcom	7	6	2	6	**4.55**
1.1.6	3 parameters (latitude, longitude, altitude) (6 wps, 0.072 kbit/s)					
1.1.6.1	Aircraft not equipped with Satcom	8	2	1	6	**3.7**
1.1.6.2	Aircraft equipped with Satcom	8	6	2	6	**4.7**

1.2	**Triggered transmission of flight data when an upcoming catastrophic event is detected**					
1.2.1	Audio from CVR (Cockpit Area channel 1 track 16kHz, 256 kbit/s)	1	2	2	1	**1.55**
1.2.2	Cockpit images (general cockpit view 4 fr/sec, 2048 kbit/s to 8 Mbit/s)	1	2	2	1	**1.55**
1.2.3	Cockpit images (general cockpit view 4 fr/sec, compressed to 256 kbit/s	1	2	2	1	**1.55**
1.2.4	All FDR parameters (up to 1024 wps,12.288 kbit/s)					
1.2.4.1	Aircraft not equipped with Satcom	6	2	1	6	**3.4**
1.2.4.2	Aircraft equipped with Satcom	6	6	3	6	**4.8**
1.2.5	Essential parameters (64 wps, 0.768 kbit/s)					
1.2.5.1	Aircraft not equipped with Satcom	6	2	1	6	**3.4**
1.2.5.2	Aircraft equipped with Satcom	6	6	6	6	**6**
1.2.6	3 parameters (latitude, longitude, altitude) (6 wps, 0.072 kbit/s)					
1.2.6.1	Aircraft not equipped with Satcom	6	2	1	6	**3.4**
1.2.6.2	Aircraft equipped with Satcom	6	7	8	6	**6.95**
1.3	**More extensive use of automatic position reporting (ADS-B)**					
1.3.1	More extensive use of automatic position reporting - ADS-B Out	9	4	4	5	**5.05**

1.3.2	More extensive use of automatic position reporting - ADS-B In	6	6	2	6	4.4
1.4	**Include parameters (position, heading, speed, altitude, accelerations…) in ACARS maintenance messages**	9	8	5	4	5.75
1.5	**Include parameters in the AOC ACARS position report messages**	9	9	6	4	6.3
1.6	**Underwater transmission of data to a vessel when approaching the location of the wreckage**	2	1	1	1	1.15
1.7	Utilize system information e.g. triangulation, spot beam to augment aircraft position					
1.7.1	aircraft equipped with swift broad band	6	2	6	4	4.8
1.7.2	aircraft equipped with classic satcom	6	6	6	4	5.4
1.7.3	aircraft equipped with Iridium				4	1.2
2	**New flight recorder technology**					
2.1	Installation of an ED-112 combined free-floating deployable recorder					
2.1.1	Retro fit case	9	2	1	8	4.45
2.1.2	Forward fit on new certificate of airworthiness	9	2	2	8	4.85

2.1.3	Forward fit on new type certificate to replace one combi + 1 ELT	9	9	7	8	7.9
2.2	**Installation of a ED-155 combined free-floating deployable recorder**					
2.2.1	Retro fit case	9	2	1	8	4.45
2.2.2	Forward fit on new certificate of airworthiness	9	2	1	8	4.45
2.2.3	Forward fit on new type certificate as an extra recorder	9	9	1	8	5.5
2.3	**Installation of one extra combined ED-155 lightweight flight recorder in the vertical stabilizer**					
2.3.1	Retro fit case	9	2	2	1	2.75
2.3.2	forward fit on new certificate of airworthiness	9	2	2	1	2.75
2.3.3	forward fit on new type certificate as an extra recorder	9	9	2	1	3.8
2.4	**Improve the attachment of the ULB (mandate compliance with EUROCAE ED-112 standard)**					
3	**Wreckage localisation technology**					
3.1	**Increased autonomy of ULBs (90 days instead of 30 days)**	10	7	7	1	5.65

3.2	**Use of a lower frequency for ULBs attached to the aircraft**	9	3	7	6	**6.4**
3.3	**ULBs transmitting only when interrogated (to improve their autonomy)**	2	1	1	6	**2.65**
3.4	**Deployable ELTs with GPS position broadcasting**	9	6	1	6	**4.45**
3.5	**Other solutions to locate the wreckage from a longer distance (area coverage of 40 nm radius within 30 days after the crash at a maximum depth of 6000 m)**	2	1	2	6	**3.05**

Appendix 3: Score justifications

The scores of each factor given to each solution are detailed below.

1.1.1 Automatic continuous real time transmission of audio from CVR (Cockpit Area channel 1 track 16kHz, 256 kbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 2 (red) Transmission rate cannot be assumed by current transmission means Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require equipment not currently installed on aircraft
Factor 2: Cost	The score is 1 (red) Installation costs are high as well as operational cost of sending 256 kbits/s of data continuously via satellite.
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 100%. The contribution to localization is null

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.1.2 Automatic continuous real time transmission of cockpit images (general cockpit view 4 fr/sec, 2048 kbit/s to 8 Mbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 2 (red) Current communication means not capable of transmitting image at 8Mbit/s. Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require equipment not currently installed on aircraft, like cameras, new satcom systems

Factor 2: Cost	The score is 1 (red) Installation costs are high as well as operational cost of sending 8 Mbits/s of data continuously via satellite.
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 100% and assuming that a image recorder existed, was installed on all 26 aircraft and was recovered the same day as the CVR. The contribution to localization is null

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.1.3 Automatic continuous real time transmission of cockpit images (general cockpit view 4 fr/sec, compressed to 256 kbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 2 (red) Transmission rate cannot be assumed by current transmission means Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require equipment not currently installed on aircraft, like cameras, new satcom systems
Factor 2: Cost	The score is 1 (red) Installation costs are high as well as operational cost of sending 256 kbits/s of data continuously via satellite.
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 50% and assuming that a image recorder existed, was installed on all 26 aircraft and was recovered the same day as the CVR. The contribution to localization is null

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.1.4.1 Automatic continuous real time transmission of all FDR parameters (up to 1024 wps, 12.288 kbit/s) - Aircraft not equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 7 (yellow) Continuous transmission is achievable using Iridium or Inmarsat services currently available and avionics presently installed on aircraft. Polar zones not covered by Inmarsat. Parameter transmission via satellite is already being tested onboard commercial flights today. Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require installation of SatCom and equipment not currently installed on aircraft, like data concentrators connected to SatCom or HF
Factor 2: Cost	The score is 1 (red) Installation cost would be well over $10K/aircraft for aircraft not already equipped with SatCom Operational cost of sending 12 kbits/s of data continuously via satellite is also high.
Factor 3: Applicability	The score is 7 (yellow) The data recoverability was computed using the formula mentioned above with k(i) set to 100% when a FDR was onboard, 0% otherwise. The contribution to localization was computed using the formula mentioned above.

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.1.4.2 Automatic continuous real time transmission of all FDR parameters (up to 1024 wps, 12.288 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 7 (yellow) Same as 1.1.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Would require equipment not currently installed on aircraft, like data concentrators connected to SatCom or HF

Factor 2: Cost	The score is 2 (red) Installation cost would be over $10K/aircraft Operational cost of sending 12 kbits/s of data continuously via satellite is high.
Factor 3: Applicability	The score is 7 (yellow) Same as 1.1.4.1

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.1.5.1 Automatic continuous real time transmission of essential parameters (64 wps, 0.768 kbit/s) - Aircraft not equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 7 (yellow) Same as 1.1.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Same as 1.1.4.1
Factor 2: Cost	The score is 1 (red) Installation cost would be over $10K/aircraft for aircraft not already equipped with SatCom Operational cost of sending continuously data via satellite is high.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability was computed using the formula mentioned above with k(i) set to 50% when a FDR was onboard, 0% otherwise. The contribution to localization was computed using the formula mentioned above.

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.1.5.2 Automatic continuous real time transmission of essential parameters (64 wps, 0.768 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 7 (yellow)

	Same as 1.1.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Same as 1.1.4.2
<u>Factor 2: Cost</u>	The score is 2 (red) Installation cost would be over $10K/aircraft Operational cost of sending continuously data via satellite is high.
<u>Factor 3: Applicability</u>	The score is 6 (yellow) Same as 1.1.5.1

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.1.6.1 Automatic continuous real time transmission of 3 parameters (latitude, longitude, altitude 0.072 kbit/s) - Aircraft not equipped with SatCom

<u>Factor 1: Technical feasibility</u>	SF 1.1 Maturity The score is 8 (green) Continuous transmission is achievable using Iridium or Inmarsat services currently available and avionics presently installed on aircraft. Polar zones not covered by Inmarsat. Parameter transmission via satellite is already being tested onboard commercial flights today. GPS information already fed into SatCom systems, therefore there is no need for any additional data concentrator Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require installation of SatCom and other equipment
<u>Factor 2: Cost</u>	The score is 1 (red) Installation cost would be well over $10K/aircraft, for aircraft not already equipped with SatCom Operational cost of sending continuously data via satellite is high.
<u>Factor 3: Applicability</u>	The score is 6 (yellow) The data recoverability is null. The contribution to localization was computed using the formula mentioned

	above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.1.6.2 Automatic continuous real time transmission of 3 parameters (latitude, longitude, altitude 0.072 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 8 (green) Same as 1.1.6.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Would require equipment not currently installed on all aircraft.
Factor 2: Cost	The score is 2 (red) Installation cost would be over $10K/aircraft Operational cost of sending continuously data via satellite is high.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability is null. The contribution to localization was computed using the formula mentioned above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.1 Triggered transmission of audio from CVR when an upcoming catastrophic event is detected (Cockpit Area channel 1 track 16 kHz, 256 kbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 1 (red) Transmission rate cannot be assumed by current transmission means Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes Robustness of trigger criteria still to be proven
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red)

	Would require equipment not currently installed on aircraft
Factor 2: Cost	The score is 2 (red) Installation costs are high as well as operational cost of sending 256 kbits/s of data continuously via satellite.
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 50%. The contribution to localization is null

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.2.2 Triggered transmission of cockpit images (general cockpit view 4 fr/sec, 2048 kbit/s to 8 Mbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 1 (red) Current communication means not capable to transmit image at 8Mbit/s. Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes Robustness of trigger criteria still to be proven
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require equipment not currently installed on aircraft, like cameras, new satcom systems
Factor 2: Cost	The score is 2 (red) Installation costs are high as well as operational cost of sending 8 Mbits/s of data via satellite ($8/Mbyte, $3/min)
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 50% and assuming that a image recorder existed, was installed on all 26 aircraft and was recovered the same day as the CVR. The contribution to localization is null.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.2.3 Triggered transmission of cockpit images (general cockpit view 4 fr/sec, compressed to 256 kbit/s)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 1 (red) Same as 1.2.2
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require equipment not currently installed on aircraft, like cameras, new SatCom systems
Factor 2: Cost	The score is 2 (red) Installation costs are high as well as operational cost of sending 256 kbits/s of data via satellite. ($8/Mbyte, $3/min)
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 50% and assuming that a image recorder existed, was installed on all 26 aircraft and was recovered the same day as the CVR. The contribution to localization is null

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2

1.2.4.1 Triggered transmission of all FDR parameters (up to 1024 wps, 12.288 kbit/s) - Aircraft not equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Transmission is achievable using Iridium or Inmarsat services currently available and avionics presently installed on aircraft. Polar zones not covered by Inmarsat. Triggered parameter transmission via satellite is already being tested onboard commercial flights today. Antenna visibility not guaranteed all the time, especially for aircraft in unusual attitudes Testing of trigger conditions to define an emergency state has been underway for several years now and while not mature by industry standards, this approach to streaming data is becoming more robust and accepted. The capability to implement complex algorithms and update these algorithms remotely has allowed for a platform to test and fine tune many trigger events.
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red)

	Would require the installation of a SatCom system Would require equipment not currently installed on aircraft, like data concentrators
Factor 2: Cost	The score is 1 (red) Installation cost (including a SatCom system) would be over $10K/aircraft Operational cost of sending 12 kbits/s of data via satellite is high.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability was computed using the formula mentioned above with k(i) set to 50% when a FDR was onboard, 0% otherwise. The contribution to localization was computed using the formula mentioned above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.4.2 Triggered transmission of all FDR parameters (up to 1024 wps, 12.288 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.2.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Would require equipment not currently installed on aircraft, like data concentrators
Factor 2: Cost	The score is 3 (red) Installation cost would be over $10K/aircraft, because transmission rate cannot be assumed by current transmission means. But the SatCom system is already installed Operational cost of sending 12 kbits/s of data via satellite is high.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability was computed using the formula mentioned above with k(i) set to 50% when a FDR was onboard, 0% otherwise. The contribution to localization was computed using the formula mentioned above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.5.1 Triggered transmission of essential parameters (64 wps, 0.768 kbit/s) - Aircraft not equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.2.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require the installation SatCom systems and other equipment
Factor 2: Cost	The score is 1 (red) Installation cost (including a SatCom system) would be over $10K/aircraft
Factor 3: Applicability	The score is 6 (yellow) The data recoverability was computed using the formula mentioned above with k(i) set to 25% when a FDR was onboard, 0% otherwise. The contribution to localization was computed using the formula mentioned above.

Source:
-Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.5.2 Triggered transmission of essential parameters (64 wps, 0.768 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.2.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Would require equipment not currently installed on aircraft, but less complex than in 1.2.4.2
Factor 2: Cost	The score is 6 (yellow) Installation cost is estimated to be less than $10K/aircraft, because it is less complex than a system transmitting all FDR parameters and SatCom already installed. There would be little transmission cost provided that the triggering criteria are robust. In most flights, no transmission would take place.

Factor 3: Applicability	The score is 6 (yellow) Same as 1.2.5.1

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.6.1 Triggered transmission of 3 parameters (latitude, longitude, altitude 0.072 kbit/s) - Aircraft not equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.2.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Would require the installation of a SatCom system and other equipment
Factor 2: Cost	The score is 1 (red) Installation cost for SatCom would be greater than $10K/aircraft
Factor 3: Applicability	The score is 6 (yellow) The data recoverability is null. The contribution to localization was computed using the formula mentioned above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.2.6.2. Triggered transmission of 3 parameters (latitude, longitude, altitude 0.072 kbit/s) - Aircraft equipped with SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.2.4.1
	SF 1.2 Equipage (aircraft/ground station) The score is 7 (yellow) Would require equipment not currently installed on aircraft, but simpler than

	for essential or all parameters because GPS information already available within the SatCom system.
Factor 2: Cost	The score is 8 (green) There would be little transmission cost provided the triggering criteria are robust. In most flights, no transmission would take place.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability is null. The contribution to localization was computed using the formula mentioned above.

Source: -Airbus contribution to WG#2
-Astrium discussion notes for Transmission of Real Time Flight Data
-Inmasat's Ideas on Flight Data Recovery using Satellites
-Iridium's contribution to WG #2
-FLYHT's contribution to WG#2

1.3.1 More extensive use of automatic position reporting - ADS-B Out

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature and is currently used. Ground stations already exist (there are 794 stations in the USA to provide national coverage). ADS-B Out is mandated depending on airspace requirements (Eurocontrol 2012 forward fit, 2015 retro fit; US 2020 all A/C) Capability exists (and is planned in the US) to record data received by ground stations
	SF 1.2 Equipage (aircraft/ground station) The score is 4 (yellow) In NPRM DOT docket No. FAA-2007-23305, ADS-B Out performance requirements would apply to all aircraft (domestic and foreign flag) operating in designated U.S. territorial airspace Limited coverage in non-radar areas
Factor 2: Cost	The score is 4 (yellow) Installation cost is less than $10K/aircraft and $25k/ground station, but ground stations are needed and more ADS-In aircraft have to be present for this solution to be useful
Factor 3: Applicability	The score is 5 (yellow) ADS-B Out – Recording limited by reception of ground station. The data recoverability is null. The contribution to localization was computed using the formula mentioned above for accidents within 300 NM of the shoreline.

Source: Airbus contribution to WG#2
-FAA contribution to WG#2 (“ADS-B system – Potential uses for Flight Data Recovery”)

1.3.2 More extensive use of automatic position reporting - ADS-B In

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) The technology is mature and is currently used. The solution would be beneficial only if all aircraft are ADS-In equipped.
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Not mandated. Requires approval for operational credit. May be recorded by data-link recording.
Factor 2: Cost	The score is 2 (red) Installation cost is greater than $10K/aircraft and $25K/ground station
Factor 3: Applicability	The score is 6 (yellow)

	The data recoverability is null, as only position parameters are transmitted. For the evaluation, it was assumed that at least one ADS-in aircraft was in the vicinity of each accident aircraft and the contribution to localization was computed using the formula mentioned earlier.

Source: -FAA contribution to WG#2 ("ADS-B system – Potential uses for Flight Data Recovery")

1.4 Include parameters (position, heading, speed, altitude, accelerations…) in ACARS maintenance messages

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature and is currently used, with the classic Inmarsat or Iridium service
	SF 1.2 Equipage (aircraft/ground station) The score is 8 (green) Not mandated, but most recent long-haul aircraft are equipped. FMC software would need to output data to CMU This solution does not propose that all aircraft be equipped with ACARS. It only proposes to include these basic parameters if ACARS is already installed.
Factor 2: Cost	The score is 5 (yellow) Cost associated with the additional parameters in the already existing messages. Cost per message is estimated to be $0.25, and each parameter would increase the cost of the message by 5%. There would also be a cost to FMC software change to output data to CMU.
Factor 3: Applicability	The score is 4 (yellow) The data recoverability is null, as only position parameters are transmitted. The contribution to localization was computed using the formula mentioned earlier, assuming that all aircraft in the list had ACARS after 1990.

Source: -Airbus contribution to WG#2
-Air France contribution to WG#2
-SITA contribution to WG#2
-Honeywell contribution to WG#2

1.5 Include parameters in the AOC ACARS position report messages

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) Same as 1.4
	SF 1.2 Equipage (aircraft/ground station) The score is 9 (green) Same as 1.4, except no change to FMS software is needed
Factor 2: Cost	The score is 6 (yellow)

	Same as 1.4, except no cost associated with FMS software change
Factor 3: Applicability	The score is 4 (yellow) Same as 1.4

Source: -Airbus contribution to WG#2
-Air France contribution to WG#2
-SITA contribution to WG#2
-Honeywell contribution to WG#2

1.6 Underwater transmission of data to a vessel when approaching the location of the wreckage

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 2 (red) Only at a stage of a design concept for most of these solutions. Recorder designs will need to be changed to provide for: (a) memory access, which may not be possible with present memory modules that flood when deeply submerged and (b) electrical power to access the memory at depth Very difficult to maintaining a hermetic seal of beacon or enclosure at great depth due to adding a communications/power interface to provide the parameters. A solution that integrates the crash survivable acoustic modem, battery into the memory module seems complex.
	SF 1.2 Equipage (aircraft/ground station) The score is 1 (red) Not currently installed on any aircraft. New equipment would be needed on the aircraft, but new submarine and ground station equipment would also need to be developed.
Factor 2: Cost	The score is 1 (red) The cost per aircraft would exceed $10K. Additional cost would be linked to maritime and ground station equipment.
Factor 3: Applicability	The score is 1 (red) The data recoverability was computed using the formula mentioned above with k(i) set to 100%. The contribution to localization was set to 0, since a pre-localization of the recorder would be necessary to receive the data acoustically from the recorder (need to be about 100 m from the recorder)

Source: -Benthos contribution to WG#2
-Dukane contribution to WG#2
-GE contribution to WG#2
-IXWaves contribution to WG#2

1.7.1 Utilize system information e.g. triangulation, spot beam to augment aircraft position - aircraft equipped with swift broad band

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Inmarsat has performed initial investigation which indicate that appropriate modems are readily available and could be deployed quickly to support all 7 Inmarsat classic aero satellites.
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Only a few aircraft (about 500) are equipped with SwiftBroadband.
Factor 2: Cost	The score is 6 (yellow) No cost for aircraft, but processing software would need to be developed and tested for the ground stations to compute trajectory of aircraft
Factor 3: Applicability	The score is 4 (yellow) The data recoverability is null The contribution to localization was computed using the formula mentioned earlier, assuming that aircraft in the list (except commuters) had SatCom after 1990.

Source: -Inmasat's Ideas on Flight Data Recovery using Satellites

1.7.2 Utilize system information e.g. triangulation, spot beam to augment aircraft position - aircraft equipped with classic SatCom

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 6 (yellow) Same as 1.7.1
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) Over 7300 aircraft are equipped with Inmarsat classic Aero
Factor 2: Cost	The score is 6 (yellow) Same as 1.7.1
Factor 3: Applicability	The score is 4 (yellow) Same as 1.7.1

Source: -Inmasat's Ideas on Flight Data Recovery using Satellites

2.1.1 Installation of an ED-112 combined free-floating deployable recorder – Retro fit case

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature. Indeed, it has been successfully used on military aircraft for over 30 years and civilian certified deployable recorders are used since 1997. FAA TSOs are in place to support implementation.
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) It would require equipment not currently installed on aircraft, like aircraft-specific trays that have to be fitted on the skin of the aircraft and onto which the deployable recorders are mounted.
Factor 2: Cost	The score is 1 (red) The equipment would cost more than $10 K/aircraft. (Equipment $25K to $30K recurring per aircraft + plus OEM Mark-up)
Factor 3: Applicability	The score is 8 (green) As it provides incident and wreckage notifications in minutes of event, this technology increases significantly the probability of wreckage localization and data recovery. The data recoverability was computed using the formula mentioned above with k(i) set to 100%. The contribution to localization was computed using the formula mentioned earlier.

Source:
- Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.1.2 Installation of an ED-112 combined free-floating deployable recorder – Forward fit on new certificate of airworthiness

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) Same as in 2.1.1
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Once an STC has been issued for a given aircraft type, no new equipment would be needed, as it would be integrated at the early stage of aircraft "manufacture". The STC would allow the deployable system to replace one fixed recorder and one ELT, as per 2.1.3 below.
Factor 2:	The score is 2 (red)

Cost	Same as 2.1.1, except that the cost might be a little less for new certificate of airworthiness aircraft. The cost would decrease further, once an STC has been issued for a given aircraft type. The STC would allow the deployable system to replace one fixed recorder and one ELT, as per 2.1.3 below.
Factor 3: Applicability	The score is 8 (green) Same as 2.1.1

Source: - Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.1.3 Installation of an ED-112 combined free-floating deployable recorder – Forward fit on new type certificate to replace one combi + 1 ELT

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) Same as 2.1.1
	SF 1.2 Equipage (aircraft/ground station) The score is 9 (green) No new equipment is needed, as it would be integrated at the early stage of aircraft design.
Factor 2: Cost	The score is 7 (yellow) For new aircraft build, recurring cost would be similar to fixed recorders. The deployable recorder would replace one fixed recorder and one ELT. But it would require certification for each aircraft type.
Factor 3: Applicability	The score is 8 (green) Same as 2.1.1

Source: - Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.2.1 Installation of an ED-155 combined free-floating deployable recorder- Retro fit case

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature.

	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Same as 2.1.1
Factor 2: Cost	The score is 1 (red) The installation cost would be more than $10 K/aircraft. (Equipment Est. $10K to $15K recurring per aircraft + OEM/Integrator Mark-Up) Plus aircraft would still be required to carry and maintain 2 fixed ED-112 recorders (there would be a total of 3 recorders onboard)
Factor 3: Applicability	The score is 8 (green) Same as 2.1.1

Source:
- Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.2.2 Installation of an ED-155 combined free-floating deployable recorder- Forward fit on new certificate of airworthiness

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature.
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Same as 2.1.1
Factor 2: Cost	The score is 1 (red) Same as 2.2.1
Factor 3: Applicability	The score is 8 (green) Same as 2.1.1

Source:
- Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.2.3 Installation of an ED-155 combined free-floating deployable recorder- Forward fit on new type certificate as an extra recorder

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green)

	Same as 2.1.1
	SF 1.2 Equipage (aircraft/ground station) The score is 9 (green) Same as 2.1.3
Factor 2: Cost	The score is 1 (red) For new aircraft build, recurring cost would be similar to fixed recorders. But the deployable recorder would have to come in addition to the 2 ED-112 recorders, which would increase weight and maintenance costs. Would require certification for each aircraft type.
Factor 3: Applicability	The score is 8 (green) Same as 2.1.1

Source: - Airbus contribution to WG#2
- DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2
- GE contribution to WG#2

2.3.1 Installation of one extra combined ED-155 lightweight flight recorder in the vertical stabilizer – Retro fit case

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature as it is already used in general aviation.
	SF 1.2 Equipage (aircraft/ground station) The score is 2 (red) Additional equipment installation is needed (wiring modification for instance)
Factor 2: Cost	The score is 2 (red) The equipment recurring per aircraft will cost more than $10 K/aircraft. It would have to come in addition to the 2 ED-112 recorders, which would increase weight and maintenance costs.
Factor 3: Applicability	The score is 1 (red) The increase probability for retrieving flight and voice data is low (Only 20% of past events had floating tail debris) The data recoverability was computed using the formula mentioned above with k(i) set to 100% only when the vertical fin was found floating. The contribution to localization was set to 10 or 5 (depending whether divers were used for recovery) only for accidents with the vertical fin floating. For the other accidents, it was set to 0.

Source: - Airbus contribution to WG#2
- GE contribution to WG#2

- L3 Com contribution to WG#2

2.3.2 Installation of one extra combined ED-155 lightweight flight recorder in the vertical stabilizer - Forward fit on new certificate of airworthiness

The evaluation is the same as the one for 2.3.1.

2.3.3 Installation of one extra combined ED-155 lightweight flight recorder in the vertical stabilizer - Forward fit on new type certificate as an extra recorder

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) Same as 2.3.1
	SF 1.2 Equipage (aircraft/ground station) The score is 9 (green) No new equipment is needed, as it would be integrated at the early stage of aircraft design.
Factor 2: Cost	The score is 2 (red) Same as 2.3.1
Factor 3: Applicability	The score is 1 (red) Same as 2.3.1

Source:
- Airbus contribution to WG#2
- GE contribution to WG#2
- L3 Com contribution to WG#2

3.1 Increased autonomy of ULBs (90 days instead of 30 days)

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 10 (green) The technology is mature. Indeed, the product is available and in use. It is qualified to TSO-C121.
	SF 1.2 Equipage (aircraft/ground station) The score is 7 (yellow) 90 day-ULBs are already on the market and used by some operators. The existing mounting brackets on the recorders can be used so it will have no impact on retrofit.
Factor 2: Cost	The score is 7 (yellow) One unit costs less than $1000. But there are costs associated with configuration management (Part Number matching)
Factor 3: Applicability	The score is 1 (red) The data recoverability is null. The contribution to localization was set to 10 when recorder(s) were recovered between 30 and 90 days after the accident.

Source:
- Dukane contribution to WG#2
- Benthos contribution to WG#2
- Honeywell contribution to WG#2

3.2 Use of a lower frequency for ULBs attached to the aircraft

Factor 1: Technical feasibility	SF 1.1 Maturity The score is 9 (green) The technology is mature. Indeed, a low frequency beacons are already available and in use for military aircraft and spacecraft.
	SF 1.2 Equipage (aircraft/ground station) The score is 3 (red) Not installed on public transport aircraft, but most ships equipped with acoustic means already have the capabilities to receive signals between 2 and 10 kHz.
Factor 2: Cost	The score is 7 (yellow) The price for a single unit is roughly $7000, but installation and certification costs have to be taken into account.
Factor 3: Applicability	The score is 6 (yellow)

	This technology would improve the detection range. (Comparing the standard ULB at 37.5 kHz, for the same output power, range increases from 1 Nm to 4 Nm). Thus, this device would decrease the time needed to search. The data recoverability is null. The contribution to localization was computed using the formula mentioned earlier.

Source: - ACSA contribution to WG#2 ("New Technology for faster SAR operations")
- Benthos contribution to WG#2
- Dukane contribution to WG#2
- iXWaves contribution to WG#2

3.3 ULBs transmitting only when interrogated (to improve their autonomy)

<u>Factor 1: Technical feasibility</u>	SF 1.1 Maturity The score is 2 (red) The technology is not mature. The integration of the receiving circuitry into the existing equipment has not been designed yet. The additional circuitry of a responding ULB would increase the complexity and as a result the inherent reliability would be decreased
	SF 1.2 Equipage (aircraft/ground station) The score is 1 (red) Only at a stage of a design concept.
<u>Factor 2: Cost</u>	The score is 1 (red) Would require development, tests, certification and installation. Would also require a specialized ship for the recovery with the appropriate equipment to interrogate the ULBs.
<u>Factor 3: Applicability</u>	The score is 6 (yellow) Battery consumption can be minimized until the ULB has detected an interrogation signal. Thus, the autonomy is improved and the probability for recovery is increased. The data recoverability is null. The contribution to localization was computed using the formula mentioned earlier.

Source: - Dukane contribution to WG#2
- Benthos contribution to WG#2

3.4 Deployable ELTs with GPS position broadcasting

<u>Factor 1: Technical feasibility</u>	SF 1.1 Maturity The score is 9 (green) The technology is mature. Fully qualified military system exists today and the path to civilian certification is easy. FAA TSOs are in place to support

	implementation.
	SF 1.2 Equipage (aircraft/ground station) The score is 6 (yellow) New equipment would be needed on the aircraft, but the feasibility is proven on helicopters for over 30 years.
<u>Factor 2: Cost</u>	The score is 1 (red) The cost per aircraft exceeds $10K. Would only replace one existing ELT. The 2 ED-112 recorders would still have to be installed. The cost to design an aircraft-specific tray “only” for an ELT is not justified, since in that same tray a deployable recorder with ELT could be installed.
<u>Factor 3: Applicability</u>	The score is 6 (yellow) As it provides an immediate incident alert and notification of a downed aircraft, it increases the probability for wreckage localization and data recovery. The data recoverability is null. The contribution to localization was computed using the formula mentioned earlier.

Source: - DRS contribution to WG#2
- EADS Defence&Security contribution to WG#2

3.5 Other solutions to locate the wreckage from a longer distance (area coverage of 40 nm radius within 30 days after the crash at a maximum depth of 6000 m)

<u>Factor 1: Technical feasibility</u>	SF 1.1 Maturity The score is 2 (red) The following solutions were presented: ▪ 3 kHz ULB (Dukane) ▪ Ejection buoy (ACSA) ▪ Autonomous submarine with laser gated camera (ACSA) ▪ Broadband signal ULB (Benthos) ▪ Underwater acoustic communications, data processing, data storage and underwater data uploads (Benthos) ▪ Systematic recording of the signals and possible post-processing (IXWaves) ▪ Signal broadcasting to ground-based stations and networks (IXWaves) ▪ Beacon activation (IXWaves) ▪ Dropping strategies and survey scanning (IXWaves) ▪ Navy multi-sonobuoy network (IXWaves) ▪ TPL and other towed platforms (IXWaves) ▪ Submarines (IXWaves) ▪ AUV (IXWaves) ▪ Vertical glider (IXWaves) ▪ Improved Towed Pinger Locators (IXWaves) ▪ Heterodyne beacons for a transitional period (IXWaves) ▪ Lost-fibre radio buoys (IXWaves) ▪ 37.5 kHz ULB : energy management, local intelligence, continuous ▪ Emission, sleep mode, reduced uncertainties (IXWaves) ▪ Dimensional, energy, and functional specifications (IXWaves) ▪ SSD (Solid State Drive) recorder (IXWaves) ▪ Remote reading, integrated modem (IXWaves) Most of these solutions are at a stage of a design concept.

	SF 1.2 Equipage (aircraft/ground station) The score is 1 (red) New equipment would be needed on the aircraft, and also submarine and ground stations.
Factor 2: Cost	The score is 2 (red) The cost per aircraft would exceed $10K for most of these solutions. Additional cost would be linked to maritime and ground station equipment, even if some of them already exist.
Factor 3: Applicability	The score is 6 (yellow) The data recoverability is hard to assess, but most of these solutions would contribute only to localization (except maybe for acoustic data transmission). Therefore data recoverability was set to 0. The contribution to localization was computed using the formula mentioned earlier.

Source:
- ACSA contribution to WG#2 ("New Technology for faster SAR operations")
- Benthos contribution to WG#2
- Dukane contribution to WG#2
- IXWaves contribution to WG#2

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