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**THIRD MEETING OF ASIA/PAC OPMET MANAGEMENT TASK FORCE  
OF CNS/MET SUB-GROUP OF APANPIRG (OPMET/M TF/3)**

Bangkok, Thailand, 2-4 March 2005

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**Agenda Item 5: Transition to BUFR coded OPMET information**

**REPORT OF THE EUR BUFR ASSESSMENT TASK FORCE**

(Presented by Secretariat)

**SUMMARY**

Attached to this paper is the report of the first meeting of the BUFR Assessment Task Force of the METG of the EANPG held in September 2004 at the ICAO Office, Paris.

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**EANPG**

**BUFR Transition Assessment Task Force**

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**Report on the Proposed Transition for  
Meteorological Messages from  
Traditional Alphanumeric Codes (TAC)  
to Binary Universal Format (BUFR)**

**Issue 1.1**



## DOCUMENT IDENTIFICATION SHEET

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<b>Abstract</b>		
<p>This paper assesses the impact of the transition from Traditional Alphanumeric Codes (TACs) to Binary Universal format for the Representation of Meteorological Data (BUFR) within the EUR Region. It lists the benefits and problems associated with the transition and suggests how the transition could be implemented on national, regional and global basis. It suggests that a number of significant items of work need to be completed including pilot studies, the production of specifications for BUFR conversion and the implementation of AMHS with the EUR ATSMHS Profile as a minimum before transition can be implemented.</p>		
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## LIST OF ACRONYMS

AFS	Aeronautical Fixed Service
AMHS	Aeronautical Message Handling System
ATSU	Air Traffic Service Unit
BUFR	Binary Universal Format for the Representation of Meteorological Data
ET/DRC	Expert Team Data Representation and Codes
GRIB	Gridded Binary data
GTS	Global Telecommunications System
ICAO	International Civil Aviation Organisation
IROG	Inter Regional OPMET Gateway
ISCS	International Satellite Communication System
METAR	Aviation Routine Weather Report
OPMET	Operational Meteorological information
SADIS	Satellite Distribution System for Information relating to Air Navigation
SIGMET	Information concerning en-route weather phenomena which may affect the safety of aircraft operations
SPECI	Aviation Selected Special Weather Report (in aeronautical meteorological code)
TAC	Traditional Alphanumeric Code e.g. FM15 METAR
TAF	Aerodrome Forecast
TDCF	Table Driven Code Format .e.g. BUFR
WAFC	World Area Forecast Centre
WAFS	World Area Forecast System
WMO	World Meteorological Organisation

# 1 EXECUTIVE SUMMARY

1.1 BUFR is a Table Driven Code Form (TDCF) developed by the WMO that can be used to encode meteorological data using a self describing code which is presented in a binary form. The WMO is currently transitioning its existing Traditional Alphanumeric Codes (TACs) to BUFR as a major programme covering all of the domains in which meteorological data is exchanged including aviation.

1.2 This document, on the planning for the migration to BUFR (Binary Universal Form for the Representation of meteorological data) encoded OPMET Messages, has been produced by the BUFR Transition Assessment Task Force in response to Decision 45/13 of the EANPG.

1.3 The Task Force considered a number of issues in relation to the migration from TAC to BUFR in the aviation domain. These issues included an assessment of the benefits to the aviation community of a full transition to BUFR, an assessment of the different approaches to transition and whether or not the proposed transition time frames are realistic. The task force also considered whether the transition was justifiable in the aviation domain and what guidelines would be required in order to provide an ordered, safe and efficient transition if it proceeds.

1.4 The benefits of BUFR were examined and it was agreed that BUFR would produce some significant benefits most particularly by forcing the automation of systems originating BUFR encoded observations or forecasts and the use of communications protocols that included sophisticated error detection. Other benefits related to BUFR self describing nature including the ability to examine and interpret legacy data and the ability to add new parameters without code changes to the BUFR processing.

1.5 The flexibility of BUFR was however compromised by its unsuitability for human interpretation which requires that a presentation format be used. Conversion to the presentation format, assumed to be the same as the existing TAC codes, removes the benefits of flexibility and adds to the complexity of systems. It is vital however that a familiar presentation format is maintained as aviation users of meteorological data are a much broader group than for other meteorological data. Safety and liability issues, particularly in the light of forthcoming 'Single European Skies' legislation could also be a significant problem.

1.6 A fundamental element of any transition will be the development and implementation of TAC/BUFR and BUFR/TAC converters so that information in presentation format can be generated from BUFR data and legacy systems can be used during the transition period. Some conversion software is available at the moment but it needs to be developed further as it does not do the complete conversion. Any such software should be built to a standard developed by the WMO and ICAO to ensure correct and consistent operation.

1.7 National communications infrastructures for the promulgation of meteorological data are highly diverse so it is important that these infrastructures can support BUFR coded messages without problem. This situation can however be worked around by the use of TAC/BUFR and BUFR/TAC converters. States face a choice of supporting BUFR directly by updating data generating systems and end users systems or by insulating these systems from BUFR by use of converters. Special attention, in the latter case, needs to be paid to the interface between the AMHS and the TAC/BUFR Converter.

1.8 Of critical importance in relation to BUFR migration with the EUR region is the implementation of the AMHS. It is noted from the AFSG Work Programme that the implementation planning of the AMHS based on the BUFR requirements has been suspended until it can be fully justified. It is a matter of debate whether the benefits accruing from BUFR alone justify the implementation of AMHS. Although the GTS is used in some states for both national and international distribution it is not part of the AFS and its widespread use would lead to institutional difficulties including funding.

1.9 Assuming that BUFR transition does go ahead it is suggested the existing MOTNE distribution scheme be used and dual transmission of both TAC and BUFR be maintained. Once a number of qualifying criteria have been achieved states may transition to international promulgation in BUFR only. Changes will also be required to the OPMET Databanks in Brussels, Toulouse and Vienna. The transition process will need to be planned, administered and monitored by a dedicated group.

1.10 On a regional basis the same problems apply but in particular the implementation of AMHS with a minimum profile equivalent to that defined in the EUR-ATSMHS Profile is a pre-requisite for transition implementation activities. ATSMHS trials have been carried between Japan and the United States but the profile used does not support binary data.

1.11 In conclusion the paper states that BUFR does offer some useful benefits, in particular a guarantee of correctly formatted data. Other benefits however are less clear and there is a significant amount of work and cost involved in a transition both by ICAO and the states. A substantial amount of this work, production of specifications, compliance procedures and guideline material, must be carried out prior to operational transition in order to ensure that the transition process is on a firm basis. There are also issues regarding safety and liability that may further complicate the transition. The transition also has a significant dependency on the implementation of AMHS for which there is no agreed operational requirement and therefore no agreed timetable for implementation.

## 2 INTRODUCTION

### 2.1 Purpose

This paper is the report of the BUFR Transition Assessment Task Force on the proposed transition to BUFR as required by Decision 45/13 of the EANPG.

### 2.2 Content of Decision

The EANPG Decision is provided below for reference

Decision 45/13 - PLANNING FOR MIGRATION TO BUFR CODED OPMET MESSAGES

That the EANPG Programme Co-ordinating Group (COG), in consultation with ICAO, examine the implementation of the migration to Binary Universal Form for the representation of meteorological data (BUFR) coded Operational Meteorological Information (OPMET) messages. This should include:

- a) an assessment of the benefits to the aviation community of a full transition to BUFR;
- b) an assessment of the possibility of using different approaches/scenarios to transition, including the costs and benefits implications;
- c) an assessment of whether the proposed transition time frames are realistic;
- d) an assessment of whether civil aviation should undertake the World Meteorological Organisation (WMO) transition to table-driven code forms (TDCFs) within the aviation environment; and
- e) when feasible, draft material for use by ICAO in drawing up migration guidelines for the PIRGs and the modifications of Standards and Recommended Practices (SARPs) and other institutional instrument, including the production and maintenance of a presentation standard.

## 2.3 BUFR

2.3.1 The World Meteorological Organization (WMO) code form FM 94 BUFR is a binary code designed to represent, employing a continuous binary stream, any meteorological data. The WMO Commission for Basic Systems (CBS) approved BUFR at its January/February 1988 meeting. Changes were introduced at the CBS Working Group on Data Management, Sub-Group on Data Representation meetings in May, 1989 and October 1990. The changes introduced at the October 1990 meeting were of such magnitude that BUFR, Edition 2 was defined, with an effective date of November 7, 1991.

2.3.2 The transition to BUFR was agreed in principle by ICAO at the Met Divisional Meeting held at Montreal in September 2002 although the amendments to Annex 3 enabling the transition of observation and forecast information from TAC to BUFR is not expected until amendment 74 is implemented. This is expected in November 2007.

2.3.3 BUFR is a self descriptive code. Messages encoded in BUFR can contain any observational data defined in the BUFR documentation. BUFR messages contain a complete description of what those data are: the description includes identifying the parameter in question, (height, temperature, pressure, latitude, date and time, whatever), the units, any decimal scaling that may have been employed to change the precision from that of the original units, data compression that may have been applied for efficiency, and the number of binary bits used to contain the numeric value of the observation. This data description is contained in tables that are the major part of the BUFR documentation.

2.3.4 BUFR is a purely binary or bit oriented form. The bit oriented nature of the message also requires the availability of bit transparent communications systems such as the X.25 protocol. Such protocols have various error detecting schemes built in. The binary nature of BUFR also provides efficiencies in converting messages into an internally useful numeric format. With character codes the conversion from ASCII (or EBCDIC) to integer or floating point is expensive relative to the conversion from binary integers to floating point. This is probably less of an issue for the aviation domain than other meteorological data because of the large population of human end users of the data.

2.3.5 Another TDCF, CREX, which works in the same manner as BUFR but is presented in alphanumeric form was also considered however messages created in CREX were very difficult to interpret in comparison with the existing TACs.

## 3 METHODOLOGY

### 3.1 Work Breakdown

3.1.1 A number of tasks, in which information relating to the transition was examined and documented, were defined. Each task was allocated a number of Task Force members with one member acting as the co-ordinator for the task. The co-ordinator was responsible for assigning work to the other members associated with the task, collating the material and reporting to the group should there be any risk of missing the target date for delivery. These tasks were as follows:-

Ref.	Description
A1	Assessment of impact of BUFR on the provision of meteorological sensor equipment involved in the production of METARs
A2	Assessment of the impact of BUFR on the production of TAFs
A3	Assessment of the impact of BUFR on internal national communications.
A4	Assessment of the impact of BUFR on international AFS communications. This will include AMHS and SADIS.
A5	Assessment of the impact of BUFR on Airline Information Systems and 3 <sup>rd</sup> Party Briefing Systems
A6	Assessment of the impact of BUFR on ATC Information Systems
A7	Assessment of impact of BUFR on OPMET databases.

A separate assessment was made of the effectiveness of BUFR in the reduction of costs associated with code changes. This was based on a number issues raised during the examination of the other impact assessments. Detailed costs were not provided but issues associated with the transition were identified as positive and negative in terms of cost.

Ref.	Description
A8	Assessment of benefits of BUFR when code changes are introduced.

## 3.2 Full Transition Benefit Assessments

The assessments below are concerned with the impact of BUFR on existing systems. For the assessments listed below the following items should be considered.

- The cost of modifying or replacing existing equipment to support BUFR.
- The expected lifetime of equipment currently in service and the timetable for its replacement.
- Changes in life cycle costs as a result of BUFR, e.g. maintenance, change management and training
- Safety implications of BUFR usage.
- Assessments should be based on equipment and practice in a number of states. Where possible, the situation in Regions other than EUR should be considered.

## 3.3 BUFR Assessment Meeting

3.3.1 At this meeting the papers provided for each work package were reviewed so that the group could come to conclusions about the following issues: -

- What benefits would BUFR transition confer.
- What problems would BUFR transition cause
- What would be the best way to implement a transition to BUFR
- What timescale was required to carry out the transition to BUFR

3.3.2 The output from that meeting was then documented in this report. It should be noted that although some financial information was received it was felt that it would be difficult to provide sufficiently accurate costs associated with the transition because of the widely diverse systems involved.

## 4 ASSESSMENT OF BUFR BENEFITS

### 4.1 Benefits of BUFR

4.1.1 A number of benefits associated with the introduction of BUFR were identified during the production of the task reports and their subsequent discussion. These are indicated in the following paragraphs.

4.1.2 *Self Describing Code.*

BUFR is a table driven code form (TDCF) and in a TDCF the presence of a datum described in the message itself is the self-description feature. There will be a section at the beginning of the message, which defines what data are transmitted in this message. That section will in fact contain pointers towards elements in predefined and internationally agreed tables (stored in the official WMO Manual on Codes). Once this section (the Data Description Section) is read, the following part of the message containing the data (the Data Section) can be understood. The characteristics of the parameters to be transmitted must already be defined in the tables of the WMO Manual.

4.1.3 *Simple addition of new parameters.* When there is a requirement for transmission of new parameters or new data types, new elements are simply added to the WMO BUFR Tables (to be agreed by WMO). Table driven codes therefore can transmit almost a variety of data in a flexible manner. According to the WMO the definition of new codes as such is no longer necessary and new software need not to be written; expansion of tables is sufficient. BUFR can be easily expanded to satisfy all observational requirements without deviating from WMO recommendations, even to answer national needs for specific domestic data exchange, as it is presently the case in many Countries.

4.1.4 *Uniformity of data.* If BUFR is adopted then it would appear to imply that messages should become more uniform. Currently there are a number of different units used in METARs and TAFs for the same parameters. For example in the WMO definition, visibility is expressed in metres however in the United States visibility is often expressed in statute miles. The adoption of a single standard under BUFR would be a significant step forward. The political will to implement this has not yet been demonstrated.

4.1.5 *Automation issues.* As BUFR is expressed in binary form it cannot be simply typed in manually and therefore must involve a degree of automation. This automation should be capable of ensuring that there are no syntactical errors. It may even be possible for the automated input to check the quality of input data as well. This should reduce significantly the number of incorrectly formatted messages.

4.1.6 *Communications.* The binary format of BUFR code requires that data communication used for its dissemination should be a bit oriented protocol such as TCP/IP or X.25. These protocols, through the use of cyclic redundancy checks, significantly reduce the possibility of undetected corruption of the data during transmission. Whilst such protocols are used widely for TACs they can still be promulgated on asynchronous circuits which are much less secure in terms of undetected corruption.

4.1.7 *Archiving.* Because of its self describing code the historical analysis of BUFR based data will be simpler than that of TACs. The parameters used in each message will be described within the message so there is no need to adapt the analysis to code changes that may have occurred within the period being examined.

4.1.8 *Customised presentation of Meteorological Data.* The systematic nature of BUFR coding compared to TAC coding makes it simpler for automated systems to extract particular fields from the messages. This was considered to be a possible advantage with respect to providing customised material for briefing purposes and for datalinked meteorological data to aircraft.

## 4.2 Problems with BUFR

4.2.1 *Presentation to End Users.* BUFR, which is a binary code, is unsuitable for the presentation of information to end users and requires to be translated into a presentation format which end users such as flight crew can assimilate. It has been assumed that the presentation format will essentially be the same as the existing TACs used for observations and forecasts, i.e. FM15(METAR), FM16(SPECI) and FM51(TAF). This assumption is based on the difficulty in retraining the entire aviation community to interpret a new presentation standard and also has the advantage of providing some backward compatibility for legacy systems that use observations and forecasts. It is further assumed that the WMO will eventually discontinue the support of the TAC codes and that ICAO will take responsibility for maintaining the TAC standards. This necessary use of a presentation format however negates the apparent benefit described in section 4.1.2 as code changes will require modifications to the software responsible for the translation of BUFR to the TAC presentation standard and its subsequent visualisation.

4.2.2 *Impact of Code Changes on Visualisation systems.* This has already been demonstrated in the implementation of SIGWX BUFR data on SADIS. There were initial problems in obtaining a consistent visualisation of the code by a number of different software suppliers however this is due in the main to the graphical nature of the SIGWX products and should be less of a problem with observations and forecasts. Another limitation of the BUFR code though is that changes to the encoding sequence always necessitate a downstream change to the end user visualisation software. With software upgrades being priced at £10K (UKP) upwards by a number of vendors the adoption of BUFR is seen as a costly luxury by a significant number of users. When one considers that the customer base for the WAFS SIGWX BUFR extends to operators in the Least Developed Countries (LDCs) it becomes apparent that there is a serious risk that users may not have the capability to stay up to date with changes to the BUFR standard, again this has potential flight safety implications.

4.2.3 *BUFR Encoding/Decoding Software.* It has been noted that the ECMWF has produced a universal BUFR encoder/decoder that can be made available to users. The task force was also aware of a Java library developed in Germany for the

same purpose and other independently developed BUFR encoders/decoders. There are a raft of issues relating to these decoders detailed below.

4.2.4 In order to ensure consistency it will be necessary to specify a detailed mapping between the BUFR templates and the presentation TAC standards. It is assumed that this specification will be written and maintained by ICAO, WMO or jointly. This specification will need to cover not just the code conversion but also the assignment of bulletin headers and the traceability of messages as they are converted in format.

4.2.5 The task force was made aware of problems with some existing BUFR decoders that cannot decode BUFR code encoded elsewhere. It is likely that BUFR to Presentation TAC and Presentation TAC to BUFR translation will not just be developed on the ECMWF software but may use other existing decoders or decoders developed specifically for the application. In order to ensure that meteorological information is correctly encoded and decoded, any such translators should be subject to compliance testing that proves adherence to the specification referenced in the above paragraph. Decisions need to be made on the maintenance of non standard units in the conversion process, for instance will the United States continue to produce observations with visibilities in statute miles? Development of the compliance testing will require resource as will the testing and approval of the translators.

4.2.6 *Liability.* The need for compliance testing raises the issue of liability. In the event of system incorrectly decoding a BUFR message and causing an incident the liability issue needs to be examined. If software has been compliance tested there may be a risk that liability could fall on the organisation that carried out the conformance testing or perhaps even drew up the compliance test specification. This problem has already been considered in the context of SADIS where the UK Met Office has expended considerable effort trying to ensure that the graphical products produced by different workstation providers were consistent and accurate. The UK Met Office has reviewed the software with the suppliers and has produced a list of workstation companies that have produced visualisation software that can depict WAFS data in an ICAO compliant manner. A list of these companies and other workstation suppliers are available on the Met Office web site (<http://www.metoffice.gov.uk/sadis/software/index.html>).

4.2.7 *Software Safety.* It is essential that software safety standards be considered as part of the implementation of BUFR. Safety Regulation varies from state to state currently so it is probably most appropriate to examine the issues in the context of Eurocontrol material on system safety. The EUROCONTROL Safety Regulatory Commission (SRC) is tasked with developing and harmonising the safety regulation of Air Traffic Management amongst its member states. Harmonisation is achieved by the SRC publishing EUROCONTROL Safety Regulatory Requirements. Each ESARR places a duty on states to publish, in their regulatory framework, minimum regulations to address a given safety significant subject. To this end the SRC has developed ESARR 6 "Software in ATM Systems". This document is now ready for consultation by states and comments on the proposed text have been invited.

4.2.8 The application of the requirements stated in ESARR 6 to BUFR related software need to be considered in general to code developed to support the transition and in particular with respect to the code developed by the ECMWF. The ESARR 6 document mandates rigorous levels of assurance in the validity of software requirements, the verification of software, configuration management of software and the traceability of requirements through the design process. Issues involved with integrating the ECMWF software into existing or new integrated systems needs also to be considered. It may be more cost effective for suppliers to develop their own BUFR encoder/decoders under design procedures established to ensure compliance with the ESARR 6 requirements. It should not therefore be assumed that the free provision of this software will reduce significantly the cost of implementation of integrated ATC systems that support BUFR code. It is also of significant importance to know exactly how ESARR 6 is to be applied in the context of met related services provided by organisations other than ATSPs, for instance airlines and 3<sup>rd</sup> party Briefing Service suppliers.

4.2.9 *Fragmentation.* The WMO Transition Plan states that in the aviation domain the affected data types shall be METAR, SPECI, TAF, CODAR, AMDAR, WINTEN, ARFOR and ROFOR. It should be noted however that a number of meteorological related messages do not appear to be included in the transition programme. These include SIGMETs, AIRMETs, GAMETs, Volcanic Ash Advisories and Tropical Cyclone Advisories. It was noted that at the ET/CDR Meeting in Kuala Lumpur this year that a paper was presented by the United States on a BUFR template for SIGMET which appeared to encompass conventional SIGMETs, Volcanic Ash SIGMETs and Tropical Cyclone SIGMETs. There is some confusion at the moment regarding the precise scope of the proposed transition. There is a possibility that meteorological data will become fragmented in that some data will be available in BUFR or TAC form whilst other data such as Advisories and GAMETs will only be available in TAC form.

4.2.10 *Communications Infrastructure:* At the current time the main operational driver , in terms of messaging applications, for the implementation of AMHS is BUFR. The undertaking of the implementation of AMHS is a large and complex project for the EUR Region and becomes even more involved in a global context. If BUFR implementation were to provide the sole driver to the AMHS implementation then it needs to demonstrate enough benefit to justify the costs of such an undertaking. The EANPG work programme for the AFSG includes a note on ATN transition planning that work is suspended until clear operational requirements have been established. Currently although BUFR can be seen to deliver a number of benefits they do not appear to be enough to justify AMHS implementation in isolation. It should be noted though that there are other technological drivers for implementation of AMHS in the EUR region so in all probability AMHS implementation will not rely purely on the BUFR transition to justify it. The global view of AMHS implementation however is much less clear.

## 4.3 Alternatives to BUFR

4.3.1 Because of the WMO policy of migration of all codes to BUFR the use of BUFR in the aviation domain appears to be logical. There are however alternative technologies that should be considered, if not immediately certainly in the medium term, for the promulgation and presentation of meteorological data. Extended Mark Up Language (XML) is, like BUFR, a self describing code. XML is however already in widespread use and is already a major component of many aviation related systems. A good example is the AIXM exchange format used in the European AIS Database (EAD).

4.3.2 XML could be used as a substitute for BUFR. Its most obvious disadvantage, the size of XML encoded messages, could easily be mitigated by the use of standard compression. The WMO's commitment to BUFR however would seem to make such a development highly unlikely.

4.3.3 XML still may have potential as a presentation standard. Consistency can be provided by means of standard schemas which could be defined by ICAO. The use of eXtensible Style Sheets (XSL) provide a flexible means of data presentation where standard presentations of data for different application could be developed. This also would mitigate to a large extent the software upgrade costs associated with the TAC based presentation standard (see 4.2.1).

4.3.4 The development of agreed standards for the use of XML in the aviation domain would be a significant task although there is evidence that work is already been carried out in this area.

## 5 TRANSITION APPROACHES

### 5.1 Converters

5.1.1 For transition to be carried out it is essential that conversion programmes are available that convert BUFR code into TAC and vice versa. As has been discussed earlier there are a number of issues relating to the conversion programmes relating to specification, compliance and liability.

5.1.2 It was noted that some states had attempted to use the ECMWF conversion software and had run into problems with it, especially as it was written in FORTRAN. A suggestion was made that a conversion programme written in perl would be more easily applied to a range of existing systems. It may be a valuable exercise for ICAO to investigate the requirements for a converter for use by aviation users, especially by states where budgets are constrained. This software could then be commissioned and developed and made available to aviation users.

5.1.3 The integration of conversion software into highly complex and closely integrated ATC systems is likely to be expensive. The implications of trying to integrate foreign code into what are sometimes highly proprietary and complex systems are significant costs with respect to development, testing and transition into service.

5.1.4 It is essential that the specification for BUFR/TAC conversion ensures that the conversion process is not affected in any way by the inclusion of supplementary information that a state may include in BUFR data. If not there is a risk that data, especially if it is promulgated internationally in BUFR format only, may be indecipherable by a significant proportion of users should such supplementary information disrupt the conversion process. In a similar manner ICAO and WMO should at the minimum

- specify minimum standard BUFR templates for the various data types
- define a process where changes to templates are first tested to ensure they do not disrupt the conversion process before they are implemented operationally.

5.1.5 Assuming that it is not possible to ensure that all states adhere to uniform units for observations and forecasts (see 4.1.4) then TAC/BUFR and BUFR/TAC converter specifications should take into account how best to handle situations where the unit used for the original data is presented in a different unit as part of the output of the BUFR/TAC conversion, for example the expression of horizontal visibility in metres or statute miles. Care must be taken to ensure that any rounding errors involved do not have a potential impact on operational minima.

## 5.2 National Approaches

5.2.1 There is considerable variation in progress on the use of BUFR within the EUR Region. A few states have already embarked on development work for the generation of BUFR code at source but in general little progress has been made and it is thought likely that most states will continue to produce only TAC data at source for a significant period of time.

5.2.2 Investigation into the plans of various states for the internal distribution of meteorological data have also shown enormous variation between states. Some states already have internal communications systems capable of supporting binary, some are planning to implement such system in the next few years however other states are looking to migrate internal communications to AFTN over TCP/IP which is still unsuitable for binary transmission.

5.2.3 It may be possible for a state to produce BUFR compliant data even if its internal communications infrastructure is unsuitable for binary data or it wishes to retain TAC production for the origination of data. This could be carried out by implementing a TAC/BUFR converter between the national communications infrastructure and the international AMHS interface. There are at least two important issues that need to be considered with this approach.

- The TAC/BUFR Converter interface with the AMHS system must support binary messages and operate correctly. There is a case for the AMHS and TAC/BUFR interface to be included in the TAC/BUFR Specification.
- Messages that cannot be converted from TAC to BUFR because of a syntactical error in the original TAC messages must be returned to the originator immediately so that they can be corrected. This may be done automatically or manually but it must be made clear to the originators that syntactical errors will prevent the promulgation of data and corrections must be carried out with the appropriate priority.

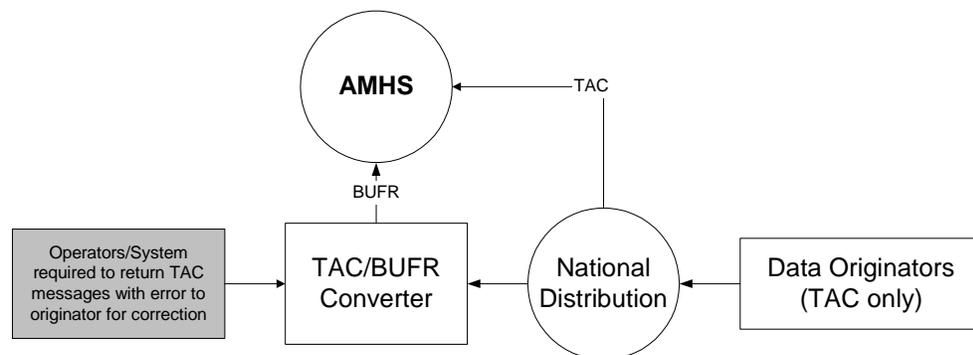


Figure 1: National TAC only System:- Output

5.2.4 During transition such a state could either receive TAC data, assuming that for the period of transition states make data available in both TAC and BUFR formats or by implementing a BUFR to TAC converter for incoming BUFR data. It is expected that BUFR to TAC conversion would be less problematic as the automatic processing required for the generation of BUFR data should be able to produce syntactically correct data that should not cause a failure to convert. This depends on a sufficiently detailed specification of the mapping between BUFR and TAC.

5.2.5 It is assumed that for each state, data will be provided in both BUFR and TAC form for at least a part of the transition period. Should a national TAC/BUFR converter be used it is possible that a state could on a given day provide all of its data in both BUFR and TAC formats in a 'big bang' scenario.

5.2.6 For states that implement systems that generate data in BUFR format transition there may be a more gradual process as production of BUFR data for each originator will only be possible when the appropriate equipment and procedures are upgraded. This gradual transition may cause confusion if only a subset of national data is available in BUFR format. It may be advisable to delay any international promulgation of BUFR data, on an operational basis, until the entire state's output is available in BUFR format.

5.2.7 Another issue worth considering on a national level is the compliance of military observations and forecasts with both existing codes and the new BUFR codes. Requirements are often stated for military aerodrome meteorological reports on basis that they may be used as emergency diversions. Currently military messages are not always compliant with existing TAC code formats, for instance the addition of colour codes. It is therefore important that these issues be taken into account when specifying TAC to BUFR conversion. It is also essential that should the military migrate to BUFR that they use templates compatible with those specified by the WMO and ICAO otherwise their data may become unusable.

5.2.8 The centralised TAC/BUFR converter approach may be attractive to states that do not wish to invest immediately in extensive upgrades to existing observation and forecasting system so long as the cost of the converter and the overheads of running it are low enough. In states where Meteorological Institutions exclusively provide observation and forecast services it may be more cost effective for the systems to be upgraded to BUFR as part of the larger WMO migration to BUFR codes. It should however be recognised that this is not the case in all states, and that in many states observations at least are provided by ATC staff, trained as observers, either manually or with the aid of Semi Automatic Met Observation Systems (SAMOS). It should be noted though that this approach will restrict the possibilities of adding supplementary national data in BUFR format (see 4.1.3) as such data cannot be promulgated in TAC format.

5.2.9 National approaches to transition may also be influenced by the state's regulator especially with respect to the scope of their application of Safety Related standards in the context of meteorological data systems. An important issue is the potential application of European 'Single Sky' safety requirements to not just the Air Traffic Service Providers (ATSPs) but also Meteorological Institutes and external service providers.

5.2.10 There is a question over when it can be considered that BUFR transition is complete for a state. This needs to be clarified. The possible options currently envisaged are as follows.

- a) When a state provides all of its data in both TAC and BUFR format for international promulgation although it may not be able to promulgate BUFR data internally.
- b) When a state provides all of its data in both TAC and BUFR format for international promulgation and can promulgate BUFR data internally.
- c) When a state provides all of its data exclusively in BUFR format for international promulgation although it may not be able to promulgate BUFR data internally.
- d) When a state provides all of its data exclusively in BUFR format for international promulgation and can promulgate BUFR data internally.
- e) When a state originates all of its data in BUFR format, provides all of its data in both TAC and BUFR format for international promulgation and can promulgate BUFR data internally.
- f) When a state originates all of its data in BUFR format, provides all of its data exclusively in BUFR format for international promulgation and can promulgate BUFR data internally

## 5.3 Regional Approaches

5.3.1 In view of the diversity of plans for data production and state communications systems it is essential the state of readiness of all EUR states should be documented and monitored so that a viable transition process can be planned. This process is likely to be time-consuming, difficult and technically demanding.

5.3.2 In terms of international communications it would appear that aside from the pan-regional satellite based services such as ISCS and SADIS the only viable AFS option is AMHS. It has already been noted that the basic AMHS profile, defined in the SARPS does not support binary messages, however it was not expected that the full Extended Profile would be implemented until some time in the future. In the meantime Eurocontrol has developed a first version of the European ATS Message Service Profile. The EUR-ATSMHS Profile will also be submitted to the ICAO/ACP Working Group N for possible global adoption. This profile includes the support of binary messages, via the use of File Transfer Body Parts.

5.3.3 At AFSG/7 it was noted that no implementation planning based on BUFR OPMET requirements should be undertaken until the EANPG had decided on the issue of BUFR transition. Assuming that planning of the AMHS recommences following the EANPG, the initial implementations of EUR-ATSMHS Profile are expected on the next 1 to 2 years. Without operational requirements and the related regional implementation plans, general implementation of the AMHS in the EUR Region will be driven by technical issues only. The timescale for full implementation is therefore impossible to determine.

5.3.4 The use of GTS for the promulgation of data is possible. Some data today circulated within the EUR region is sourced via the GTS rather than the AFS. A more major role for the GTS in the promulgation of aviation related met data is considered unlikely as it could have profound effects in terms of cost recovery and connectivity with aviation users. The GTS will however be an invaluable asset when it comes to carrying out experimental exchanges for the evaluation of various aspects of the transition, e.g. TAC/BUFR converters.

5.3.5 Both BUFR and TAC data would be promulgated within the EUR Region by MOTNE centres although additional procedures will have to be introduced for BUFR data. The control and monitoring functions of the existing MOTNE scheme as administered by the Bulletin Management Group (BMG) would be essential in planning and implementing the transition within the EUR Region.

5.3.6 Transition will be an evolving process and initially there will probably be only a relatively small amount of data available in BUFR form. This should improve as the number of states supporting BUFR increases. This increasing availability of BUFR data must be tracked and documented by a regional group so that it is clear at any given time what data is available in BUFR format and on what bulletins it is promulgated.

5.3.7 It is assumed that initially at least all states will promulgate data internationally in both TAC and BUFR format. This dual transmission will require additional bandwidth on the communications infrastructure but will provide the most flexible scenario in terms of making data available to states that will be in varying stages of progress with respect to the transition. At some point however it will be sensible to complete the transition by transitioning to a situation where only BUFR data is promulgated (see 5.2.10). This should only be considered however when the following conditions are met.

- A high level of confidence has been established in BUFR/TAC conversion by means of good specifications, compliance procedures and trial results.
- Formal arrangements have been made for the supply of TAC data to states that cannot support BUFR data.
- Routing has been reviewed to ensure that TACs produced by foreign BUFR/TAC converters are not routed to the originating state.

5.3.8 There is a risk that data provided to another state in BUFR form could be converted into TAC form and routed to states where it may conflict with TAC data provided by the original. It is obviously preferable when receiving data to use the data provided by the originator or a trusted local BUFR/TAC converter so it is suggested that when data is converted the location of the converter is clearly indicated in the bulletin. The group considered the most straightforward way of doing this would be to replace the CCCC part of the bulletin header with the CCCC of the location in which the converter operates. This would allow a system to differentiate between TACs for example originated in the UK (SAUK31 EGGY) from the same data produced by a BUFR/TAC converter in Washington (SAUK31 KWBC).

5.3.9 An important issue in the context of the supply of regional and pan regional data is the implementation of the EUR databanks. The databanks are currently available in Brussels, Toulouse and Vienna. In order to support BUFR a number of proposals have been suggested for the databanks

- It is proposed that a specific form of query will be defined for the BUFR code form, and the TAC form will be unchanged. Some verification will take place on all incoming queries by AFTN and only TAC query form will be allowed.
- Should a request for BUFR data be made on an AFTN line it is proposed both to answer by TAC form to such a query and send a warning message
- It is proposed to derive a TAC message for the Station, the Hour, and the Type and store it immediately for each receiving BUFR message as it will simplify the software and minimise the response time for TAC requests from the users.
- It is proposed that if a TAC message is received for the same data type, location and period as data already derived from BUFR then it shall only be overwritten if it is contained in a list of approved bulletins. This is intended to prevent the updating of data derived from the originator with data that may have been produced by a BUFR/TAC decoder in another state.

In order to support BUFR requests however the databanks must maintain connectivity with the AMHS.

## 5.4 Inter-Regional Approaches

5.4.1 The fact that SIGWX BUFR is already accommodated on the SADIS Service indicates that, in terms of communications at least, SADIS will not be significantly impacted by the BUFR transition. Observational and forecast data in BUFR format could be transmitted along with the existing SIGWX BUFR data or another PVC/socket used exclusively for the observational and forecast data in BUFR format. Although the communications infrastructure should not be significantly affected by the transition the following issues will need addressing: -

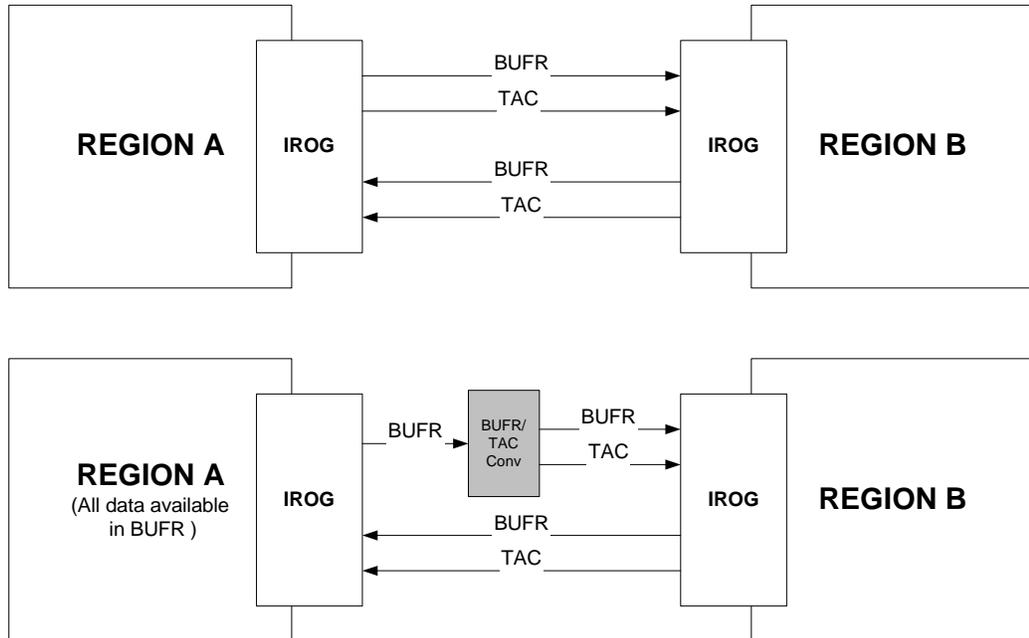
- Transition will have an impact on SADIS end user system that will have to be able to support the conversion of BUFR data into TACs for presentation to users. End user systems will also have to be able to integrate data provided in BUFR and TAC formats. It is unlikely that global BUFR coverage will be available for some time into the transition. The difficulties encountered in the provision of software capable of producing acceptable output from SIGWX BUFR on the end systems is described in paragraph 4.2.2.
- Transition will also affect the operation of the SADIS Gateway. The Gateway should continue to route data to the satellite up-link however its validation and monitoring responsibilities will be complicated by the need to decode BUFR messages in order to extract the required information. It is possible that validation will be less of an issue as BUFR production implies an automated production process that should produce syntactically correct data. Monitoring will though require at least some decoding to ascertain which data is being promulgated and whether that data is timely or not.

5.4.2 Currently data from outside of the EUR Region is received by a number of Inter Regional OPMET Gateways (IROGs), from where it is promulgated to MOTNE Centres for onward transmission within the EUR Region. Conversely data from the EUR Region is also promulgated to the other Regions via the IROGs.

5.4.3 Experience with the IROGs has shown that when errors are detected in messages from other Regions it is often impossible to obtain a timely correction from the originator. For this reason the implementation of a TAC/BUFR converter at the IROG should not be contemplated.

5.4.4 It is assumed, for the initial stages of the transition at least, that IROGs will need to exchange both BUFR and TAC data in parallel. As for Regional transition (see 5.3.4) it will be necessary to monitor and document the actual BUFR data exchanged between the IROGs in the EUR Region and elsewhere. It is suggested that a pan-regional group co-ordinate this work with regional transition groups and monitor the global progress of the transition.

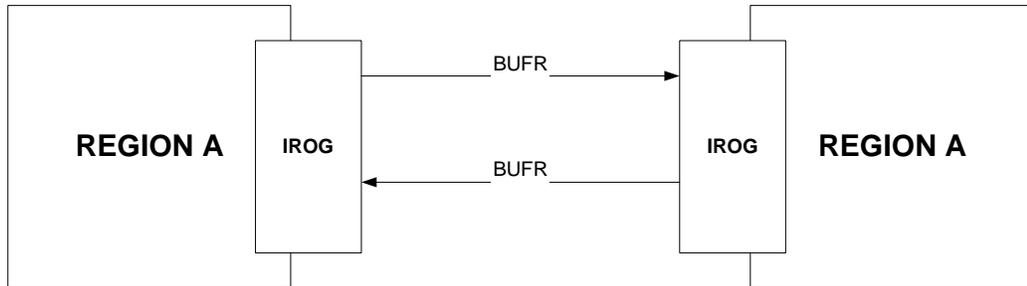
5.4.5 As the transition progresses, information on the reject rates in BUFR to TAC conversion should become available and the feasibility of implementing regional BUFR/TAC converters can be assessed. Implementation of Regional BUFR/TAC converters would enable regions, in which all internationally communicated met data is in BUFR form to cease inter-regional TAC transitions. Consider the interface between Regions A and B in the diagram below. The top diagram shows the exchange of data when not all data is available in BUFR format from Region A or B. The lower diagram shows the possible situation when all data is available in BUFR format from Region A.



**Figure 2: Inter-Regional Transition**

5.4.6 The location of the BUFR/TAC converter, at Region A IROG or Region B IROG is subject to debate. There will be some savings in terms of bandwidth if implemented in Region B but there may be other factors such as available resource and funding which could place it in Region A.

5.4.7 Assuming that the criteria for transition completion (see 5.1.10) require data exchange to be carried out exclusively in BUFR it could be said that an Inter-Regional link has completed transition when the two Regions exchange data exclusively in BUFR format, irrespective of the format of data exchange within each region, as illustrated below.



**Figure 3: Inter-Regional Transition Completed**

5.4.8 As with regional transition the use of the AMHS is essential to support BUFR transition and the basic AMHS profile does not support binary data. It was noted earlier that the EUR-ATSMHS Profile will also be submitted to the ICAO/ACP Working Group N for possible global adoption. It has also been noted that ATSMHS trials between Japan and the United States were recently completed successfully using the basic profile, i.e. it does not support the transfer of binary data. Implementation of ATSMHS between both States was originally scheduled for 10 May 2004. An announcement on the future programme is expected in November at the ACP WG N meeting in New Orleans.

## 6 TRANSITION TIMESCALE

6.1 It is extremely difficult at this stage to predict the transition timescale given that there are so many variables associated with the transition process, A number of factors that could materially affect the transition timescale are listed below.

6.2 *Presentation Standard.* It has been suggested that as a pre-requisite for transition it will be necessary to provide a specification for the presentation standard. As this is expected to be based on the existing METAR and TAF codes this should not be a significant task as they are defined in some detail in Annex 3.

6.3 *Conversion Specifications.* The production of conversion specifications will be a significant piece of work. It requires that the BUFR templates for observations and forecasts be finalised before it can be completed. The specification will include the mapping of data between TAC and BUFR. These will need to take into account unit conversions and the use of non-standard TACs as used by certain states and the military. The specification may also include rules on the allocation of bulletin headers, including the modification of the CCCC group and possibly data quality assurance checks. If these specifications are to be published as part of Annex 3 then there is a relatively limited time to develop them for inclusion into Amendment 74 to Annex 3. It may be a more flexible approach to publish them separately but it is likely that they would still require to be referenced by Annex 3. It is believed that Annex 3 Amendment 74 will come into force during 2007. Missing Amendment 74 may entail further delays to the transition.

6.4 *Compliance Standards.* As well as the specification, compliance standards will need to be developed to ensue that converters are fit for operation. This also represents a significant amount of work which if not ready for Amendment 74 may cause further delays.

6.5 *Conversion Programmes.* It is assumed that TAC/BUFR and BUFR/TAC conversion programmes cannot be used operationally until the specifications and compliance standards have been fully developed so this will represent another delay following the development of the standards before operational use can be contemplated. Safety regulations may also extend the production time of converter systems.

6.6 *Availability of AMHS.* In order to provide BUFR data operationally, AMHS must be implemented with the appropriate profile. In the EUR Region this is currently expected to be in about 5 years further delaying the transition. It was also noted that in the EUR Region work on the AMHS implementation based on the BUFR requirements has been suspended (see paragraph 4.2.10) until sufficient operational requirements have been identified to justify it. It should be emphasised however that in the EUR Region at least there are good technological drivers for AMHS transition, such as the replacement of ageing AFTN/CIDIN system and the use of a TCP/IP network instead of the increasingly obsolete X.25 technology. A clear timescale for the implementation of ATSMHS in the EUR region is not available as yet. The situation in other Regions, with the exception of ASIA/PAC, is even less clear but it is likely that some Regions will have a much slower transition to AMHS and may implement only the Basic AMHS service that does not support binary data.

6.7 *Equipment Lifecycles.* Equipment will need to be replaced at the end of its useful life and as the transition period for BUFR is relatively long it is likely that a number of systems will require replacement during this period. As soon as the standards and concept of operations for the implementation of BUFR are clearly defined it is expected that BUFR compliant products will appear on the market or can be developed internally with confidence. Until this definition is complete there will be a risk that products developed before may be unsuitable for operations. It is therefore important that all defining information as detailed above is completed as soon as possible otherwise the opportunity to replace obsolete systems with BUFR compliant ones in the next few years will be lost and the transition period will be extended.

## 7 TRANSITION GUIDELINES

7.1 Where possible all aspects of the transition infrastructure should be subject to trials using pilot projects to gather operational experience on all aspects of the transition. The results of these pilots should be made available to all states involved in BUFR transition activities. At a minimum these pilots should include the following: -

- Exchange of data originated in TAC format, translated into BUFR, promulgated and translated back into TAC. This pilot should investigate the integrity of values presented in TAC form at the receiving end.
- The promulgation of BUFR data from AMHS to national distribution systems. Given the diversity in national distribution systems a number of pilots should be carried out so that lessons learnt can be applied to as many different scenarios as possible.
- Rejection rates on national TAC/BUFR Converters. Fully functional TAC/BUFR converters need not be required for pilot projects to quantify the rejection rates associated with current TAC output. Pilots could be carried out with either national or regional scopes.

7.2 Where TAC/BUFR and BUFR/TAC converters are implemented they should be of a standard that has been approved or authorised by ICAO or some delegated authority and based on the ICAO specifications.

7.3 TAC/BUFR converters should only be implemented where syntactically incorrect TAC messages can be queried immediately and effectively. Failure to do this will result in missing or delayed data.

7.4 BUFR/TAC converters should be less problematic and there should be not significant restrictions on the implementation, provided they are compliant with the appropriate specification and have been proven through trials. Care must be taken however to ensure that TAC products produced by a BUFR/TAC converter are not routed back to the originator or other states that may receive the original TAC data from the originating state.

7.5 Further guidelines could be produced when the definition of end point of transition is made (see 5.2.10).

## 8 CONCLUSIONS

8.1 There was no unanimous opinion within the Task Force that aviation should or should not implement BUFR Transition. It was agreed by all, however that the benefits of BUFR Implementation to the aviation industry as a whole were not as substantial as they initially appeared, in particular the flexibility of code changes.

8.2 Although BUFR permitted more flexibility in the provision of information the actual benefits are extremely difficult to quantify in the absence of any concrete examples. The major benefit provided by BUFR will be the reduction of rejected messages, thus increasing the amount of useful data available for flight safety, as a result of the automated origination that BUFR will require. This will provide savings for organisations that currently validate data. This applies in particular to VOLMET and Pre-Flight Briefing systems, the MOTNE centres and the OPMET Databases.

8.2 It was also recognised that the process of BUFR transition will require significant resources if it is to be carried out in a safe and efficient manner. A number of institutional pre-requisites are necessary from ICAO including the following: -

- BUFR to Presentation TAC Specification
- Presentation TAC to BUFR Specification
- Compliance Testing

8.3 Within the EUR Region there needs to be further work carried out establishing the national communications infrastructures within individual states so that it can be established how and when these infrastructure will be capable of supporting BUFR messages.

8.4 The implementation of AMHS is also another critical issue with respect to the timescales of implementation for until AMHS connectivity is established across Europe the transition to BUFR cannot be completed. BUFR appears to be the main operational messaging requirement driving AMHS implementation in the EUR Region but the benefits conferred by BUFR at this moment in time would not appear to justify the implementation of AMHS on their own. Other technological drivers will probably ensure AMHS implementation within the EUR Region but the timescale is not clear as yet. The use of GTS should be considered for pilot projects.

8.5 Considerable investment will have to be made by states in terms of the provision of converters, the upgrading of equipment to produce and accept BUFR, and the administration of the complex processes associated with the transition. The relatively long period for transition does offer the opportunity for systems to be replaced as they come to end of their useful life although the sooner that the implementation is fully defined the sooner that systems due for replacement can make way for BUFR compliant systems.

8.5 During BUFR transition considerable resource will have to be expended in monitoring and publishing the progress of the transition, in particular the amount of data available in BUFR format and the bulletins in which they are transmitted needs to be collated on a Regional and Global basis.

8.6 The effect of impending Safety Regulation (ESARRS6) should be examined in the context of the transition. Clarification is required as to which systems this will apply to and in particular those systems that will carry out the encoding and decoding of BUFR data be they operated by Air Traffic Service Providers, Meteorological Institutes, Airlines or other third parties.

8.7 A number of significant pre-requisites have been recommended for the transition. The time taken to put these items in place could mean that the stated transition period, to 2015, may be inadequate.

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