BAE SYSTEMS

BAE SYSTEMS
Daily Ionospheric Forecasting Service

Presented by Nigel S. Wheadon

nigel.wheadon@baesystems.com

Tel: +44 (0)1245 242143

BAE SYSTEMS

Presentation Outline

- Why a need for Daily Ionospheric Forecasts (DIF) ?
  - Variability of the ionosphere
  - Users
- The BAE SYSTEMS DIF Service
  - History
  - Current service
- The BAE SYSTEMS Pilot Proposal
  - Overview of work programme

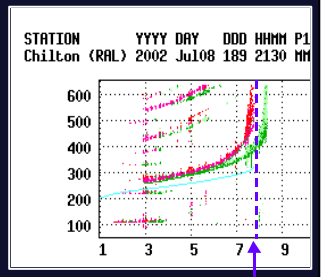
BAE SYSTEMS

Ionospheric Variability

- E region relatively predictable
- F region highly variable even on a day-to-day basis

Critical Frequencies (foF2)
20% variability about the monthly median
>40% variability during ionospheric storms

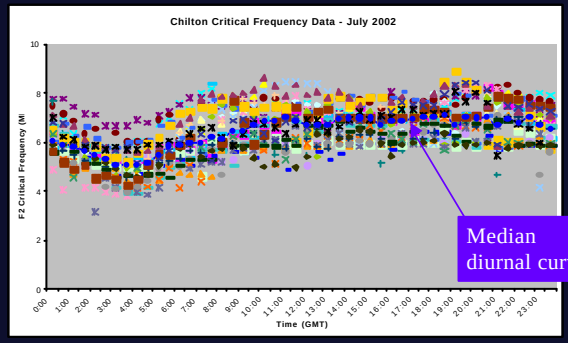
Changes in foF2 give rise to changes in the Maximum Usable Frequency (MUF)



Scaled foF2 = 7.75

BAE SYSTEMS

Chilton UK - foF2 Data - July 2002



BAE SYSTEMS

Statistical Analysis of foF2

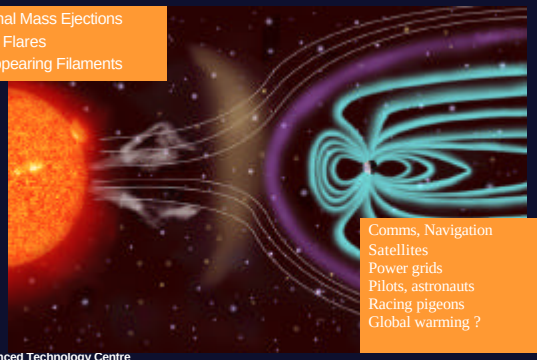
- Spatial correlation
  - 250-1000km in the European sector
  - Other latitudes & sectors vary
- Temporal
  - 15-60 minutes European/Australian sectors

Ionosphere appears to be very unpredictable !

BAE SYSTEMS

Causes & Effects

- Coronal Mass Ejections
- Solar Flares
- Disappearing Filaments



Comms, Navigation
Satellites
Power grids
Pilots, astronauts
Racing pigeons
Global warming ?

BAE SYSTEMS

Why do we need a forecast ?
An HF sky-wave user's perspective

- Highly mobile users (short range)
  - Hand-held, man-pack, vehicle or platform mounted
- Fixed to mobile (short to medium range)
  - Search & Rescue (NVI mode)
- Fixed to fixed & mobile (medium to long range)
  - Long range (Beyond Line Of Sight) comms to aircraft
  - Long-haul world-wide point-to-point circuits

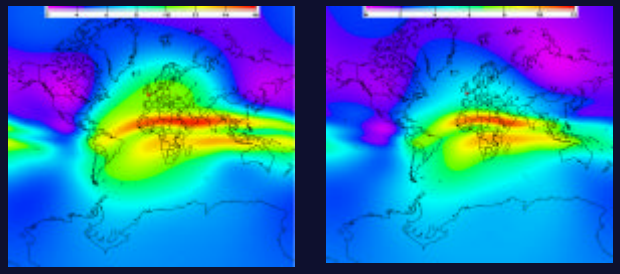
BAE SYSTEMS

HF Frequency Schedule

- Operating the circuits requires a frequency schedule
- Planned several months in advance
  - Uses internationally recognised HF sky-wave propagation prediction program
  - Frequencies assigned based on analysis
  - Additional assignments provided to cover ionospheric storms
- However which frequency does the user select today?
  - Normal daily variations
  - Predictions of storm periods & ionospheric disturbances

Ionospheric Maps

- Modify the ionospheric maps for storm periods

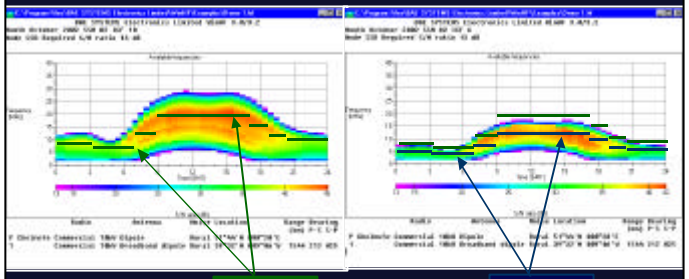


Advanced Technology Centre

HF sky-wave circuit prediction

Median Conditions

Storm Conditions



Channel Assignment

Modified Channel Assignment

Advanced Technology Centre

A SATCOM Operator's Perspective

- High link availability for critical missions
  - Plan for degradation due to scintillation outages
    - re-route to other satellites (GEO -> LEO)
    - other bearers (landline, HF, tropo, …)
- Protection of the satellites
  - Surface & internal charging / discharging
  - Protection of solar panels

Advanced Technology Centre

Other users'

- Navigation
  - Loss of lock (PLL)
  - Safety critical systems using GPS (>~30m quoted in literature)
    - Aircraft Instrument Landing Systems
    - Search & Rescue
- Radar
  - Satellite debris/junk
  - High precision threat analysis

Advanced Technology Centre

Future Military Systems

- UK approach
  - UK MoD are not buying satellites for strategic comms
  - Provision of a service contract with industry
    - SLA - Service Level Agreement
      - Pay-per-use
      - Quality of Service (QoS)
        - » Guaranteed delivery
        - » Cheap rate usage
        - » Resources only when needed (minimum provision)

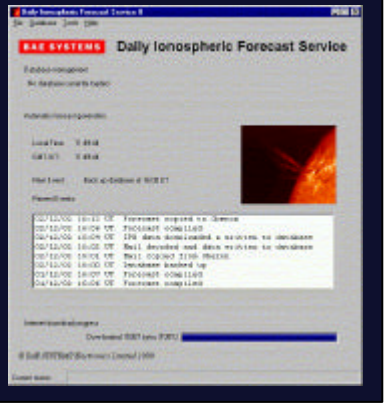
History of Ionospheric Forecasting at BAE SYSTEMS

Formerly GEC -Marconi Research Centre - Founded in 1938

- 1940-45
  - Provided support to Air Ministry, UK MoD
  - Mainly looked at HF system performance
  - Ionospheric sounder (rhombic antenna)
- 1945-1970
  - No forecasting service
  - HF system design
- 1970-1988
  - Long-term HF predictions for MoD - Quarterly 'Orange' Book
  - Daily HF propagation reports & predictions
- 1989
  - Developed world's first automated forecasting service
- 1990-present
  - Various up-grades & improvements

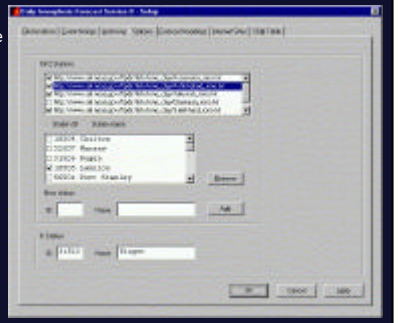
Daily Ionospheric Forecast System

- PC WindowsNT
- internet via corporate network
- Windows application
- Fully automated
  - 365 days a year
  - Daily Forecast sent via e-mail
  - Forecast also available via fax (Mon-Fri)



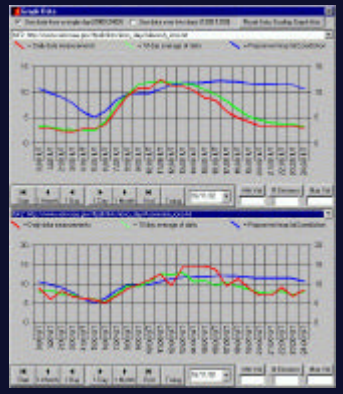
Automated Processing Data collection & storage

- Key features
  - download ionospheric data from the internet
  - solar & geomagnetic parameters
  - read & extract data from emails
    - e.g. URSIGRAM data
  - database storage
    - maintained & archived automatically



Automated Processing Algorithms & Analysis

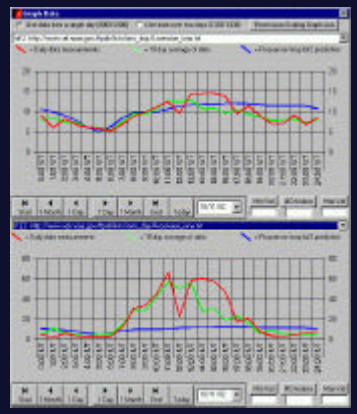
- Forecast compilation
  - algorithm development
    - persistence
    - transient phenomena
  - solar activity
    - Flares etc
  - geomagnetic storms
    - K indices
    - SSC
  - foF2/MUF analysis
  - absorption events



Advanced Technology Centre

TEC Measurement

- Similar analysis to foF2 data
- Display current data
- Display recent mean data



Advanced Technology Centre

Automated Processing Distribution

- Distribution
  - email (365d)
  - Fax (working days)

Example forecast
Three parts

1) Contact details

2) Past 24hr Summary

3) 24hr Forecast

Advanced Technology Centre

```
BAE SYSTEMS ADVANCED TECHNOLOGY CENTRE

DAILY IONOSPHERIC FORECAST FOR EUROPE
=====================================
REGION (35N-67N 15W-30E)
CONTACT: NIGEL WHEADON
TEL: 01245 242143
FORECAST ISSUED 16:06UT : 27 Nov 2002

PAST SUMMARY 12-12 UT 26 Nov-27 Nov
===================
HF SKYWAVE MUF VARIATIONS
  12-18    18-24    00-06    06-12 UT
  80- 90   65- 95   50-100   75-100
DAYTIME LUF           : NORMAL
SHORTWAVE FADES       : NONE
GEOMAGNETIC ACTIVITY  : 26 Nov
A = 15 (UNSETTLED)
SUNSPOT NUMBER        : NO DATA
10 CM FLUX VALUE      : 142

FAIR TO POOR HF RADIO CONDITIONS
PREVAILED FOR THE PAST 24 HOURS.
A MAGNETIC STORM IS IN PROGRESS.

FORECAST  1800-1800 UT 27 Nov-28 Nov
====================
HF SKYWAVE MUF VARIATIONS
  18-24    00-06    06-12    12-18 UT
  DOWN     DOWN     DOWN     NORMAL
DAYTIME LUF           : NORMAL
SWF PROBABILITY       : 15 PERCENT
GEOMAGNETIC ACTIVITY  : 28-30 Nov
A = 18/18/20 (ACTIVE)
IONOSPHERIC CORRECTION FACTOR : 6

POOR HF RADIO CONDITIONS ARE EXPECTED
UNTIL 1200UT WITH SLIGHT IMPROVEMENT
LATER.
NORTHERN CIRCUITS MAY BE DISTURBED AND EXPERIENCE
INCREASED LEVELS OF
ABSORPTION.
THE MAGNETIC STORM WILL CONTINUE FOR 18HOURS.
THE MUFS ARE GENERALLY EXPECTED TO BE
DEPRESSED.
```

ESA Space Weather Proposal

- Our proposal is to implement new services for the provision of space weather forecasting for HF and SATCOM communicators making full use of the information available via SWENET and other data sources. These services will be generated using an automated system and distribution will be via email and a web-server.

- The outputs will be various study reports and the provision of services for HF and SATCOMs users.

Advanced Technology Centre

BAE SYSTEMS

ESA Pilot Proposal - Year 1

- Year 1
  - military & civil requirements for services
    - format, information, frequency
  - data sources, local sensors, SWENET, COST, WDC, …
  - development of services
    - more frequent HF forecasts
    - forecasts for satellite communications community

BAE SYSTEMS

ESA Pilot Proposal Year 2

- Year 2
  - automated service provision
  - collection of metrics
  - accuracies & improvements
  - exploitation

BAE SYSTEMS

Summary

- The Requirement for Daily Ionospheric Forecasts
  - HF comms users
  - Support to Satellite operators (Comms, Navigation)
  - Mitigate effects on systems due to variability of the ionosphere
- The BAE SYSTEMS DIF Service
  - History
  - Description of the Current service
- The BAE SYSTEMS Pilot Proposal
  - Key features of the work programme

BAE SYSTEMS

BAE SYSTEMS
Daily Ionospheric Forecasting Service

nigel.wheadon@baesystems.com
Tel: 01245 242143