AUTOMATIC AX.25 POSITION AND STATUS REPORTING

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For the last two years the Naval Academy has used a packet radio network for communications with its boats during summer cruises. The packet radio system not only provides the connectivity typical in AX.25 radio networks for the exchange of messages, but the automatic beacons from the afloat units provide near realtime position reporting of the units at sea. The purpose of this article is to describe the Academy system, particularly the use of beacons for position and status reporting and to suggest the advanatages of such a system for use in emergency situations and network management in other AX.25 packet systems. Detailed formats for automatic position and status reporting are provided. In any communication network for any purpose, station location and status reporting are at least the second most important function, if not the first.

PACKET RADIO TACTICAL COMMUNICATION NETWORK

The objective of the AX.25 network at the Naval Academy is to provide position and status reporting and to permit the exchange of record traffic between the Academy and its fleet of almost forty Yard Patrol craft (YP's) and sailboats. The exchange of message traffic is straight forward using the internal PBBS of one Kantronics KAM, linked by Kantronics KA nodes to three HF channels, one VHF frequency for local operations, and one UHF SATCOM channel. (A description of the satellite portion of this network were published in the 1992 AMSAT Technical Symposium in October 1992) The innovation in the network, is the use of periodic packet beacons for position and status reporting. Central to the success of this beacon system is a special program which monitors the packet channels and accumulates the position and status beacons and then provides a tactical color map display of the location of all units on a scaleable map of the East Coast.

HARDWARE IMPLEMENTATION

For reliability, computers were initially avoided in the system. The master station first consisted of three dual port TNC's, one on each HF frequency. The audio from the VHF ports of these three TNC's are all summed together and fed to the SATCOM transceiver and local VHF transceiver as shown in figure 1. This simple audio node serves as a local area network to link everything together without additional hardware and node complexities. The KA node function built into the dual port TNC's manages traffic between the TNC's. The message mailbox system is simply the 16K PBBS internal to the one TNC on the 6 MHz frequency. This PBBS can be accessed directly from HF on 6 MHz, from VHF, and from the SATCOM system via the audio node. On the two other HF frequencies, the boats must first connect to the KA node TNC on that frequency, and cross i-ink to the PBBS (via the audio node). Kantronics KAMS were used initially for their dual port and KA-node capability at the master station: but because the KAMS have no way to manually initiate the forwarding of a message from one PBBS to another, we are now buying MFJ's and PACCOM TNC's for the remaining boats.

The master station is further available to officers and staff via the Academy local area network (LAN) which provides a serial port in every office at the Academy, Again, without complexity, this was accomplished simply by connecting the TNC IRS-232 serial port to the network and programming the network to recognize that address as a Host. This LAN interface allows duty officers to log into the TNC PBBS from anywhere in the Academy as well as dial-up from home to list and read message traffic. A one-transistor interface between the "CONNECTED" LED on the TNC and the LAN handles the "ready" and "busy" handshaking. Three similar TNC interfaces permit HAMS on the Naval Academy LAN to access MIR, DOVE and the local packet network.

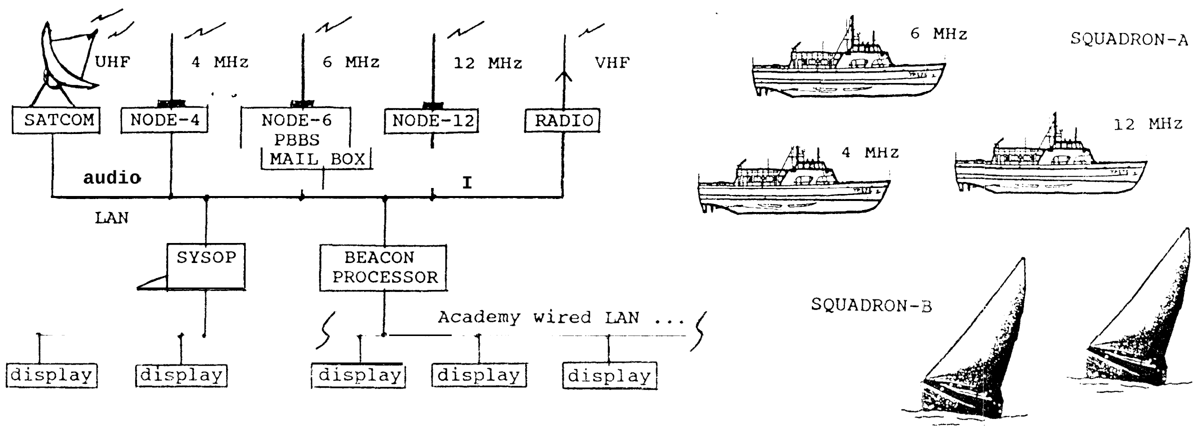


Figure 1. The Academy Network consists of three HF nodes integrated with a local VHF frequency and UHF SATCOM system via dual-port KA nodes. By August 92, 10 boats were configured with packet radio.

POSITION REPORTING BEACONS

To take advantage of propagation openings on HF, all units in the network are programmed to transmit a periodic beacon signal once every ten minutes. For the boats, the beacon is loaded with position and status. For the master station at the Academy, the beacons include short announcements or lists of traffic pending. On the boats, a casual glance at the time of receipt of the last beacons on the CRT terminal indicates propagation conditions. If the last beacons were received in the last 10 minutes, then conditions are probably good for message traffic.

At the master station during the first summer, all position report beacons from the boats were logged on a printer. The beacons were foramtted so that position, course, speed, fuel, water, casualties, next port, estimated time of arrival, and intentions were all included in the single line beacon text. By the second summer a computer program was written to parse and sort all beacons and display the position and movement of the boats in full color graphics which included charts of the entire East coast with user selected scales of 4 to 1024 miles.

To be sure that beacons on all frequencies are visible to all users, particular attention was made to the setup parameters in each TNC. First, all TNC's on the boats are set to beacon via the address ECHO. Then the gateway callsign of the three dual port TNC's at the Academy are programmed with this callsign of ECHO. This way, a beacon originating on any one HF frequency is digipeated (ECHOed) onto the master station audio node which in turn goes out on VHF and SATCOM. Any beacon originated on VHF or SATCOM is similarly digipeated (ECHOed) out on all three HF frequencies. A Beacon can be further distributed from one HF frequency onto the local VHF node and then back out on the other two HF frequencies by simply beaconing via ECHO, ECHO.

POSITION and STATUS DISPLAY SOFTWARE

The key to the success of the packet reporting system is the position and status display software which provides everyone with fresh graphic display information *on* the position and status of all units. The use of computer displays in real time is far superior to the colored pins on a wall chart which had been used for position display in the past. The tactical display using EGA graphics shows a map of the East Coast at any scale between 4 to 1024 mile range centered anywhere from Nova Scotia to the Florida Keys. A picture of the display showing several units enroute to New York is shown in figure 2. Using the cursor, any unit may be selected for a detailed display of data on that unit. Further, a single key stroke will dead reckon all unit positions to their estimated current positions based on course and speed from their last reported

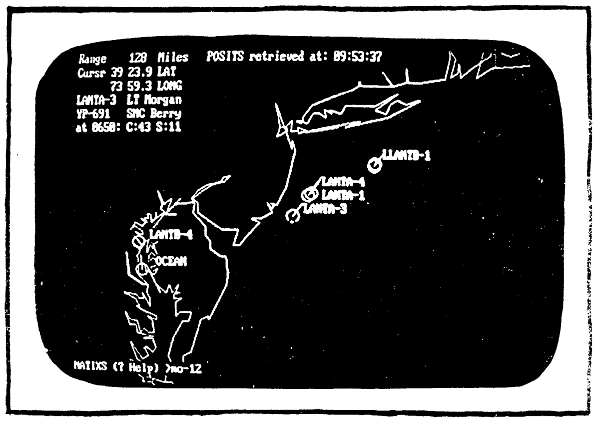
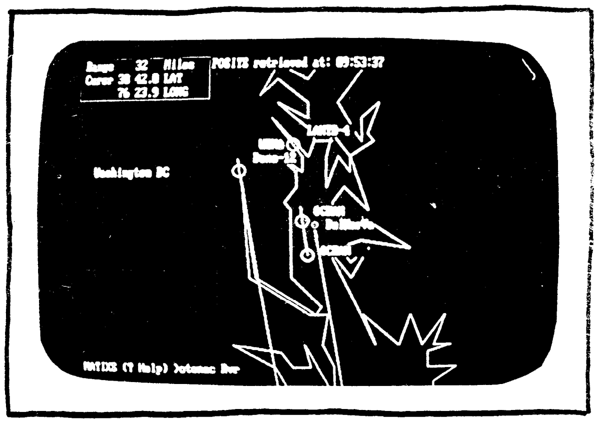


Figure 2. The tracking and display software can display the location of all packet units to any scale from 1024 down to 4 miles. Here, several units are enroute to New York.



position. It is this tactical display software which would be useful in other AX.25 packet radio networks for displaying the location and status of all participating stations.

REMOTE TELEMETRY VIA PACKET

An interesting sidelight to the packet network was the use of a Kantronics Telemetry Unit on one boat to monitor seven channels of engine conditions remotely and dump these readings over the packet radio link. Unfortunately the only way to locate engine readings of interest was to transmit every single data sample (16K per day) over packet and then search for the few high and low readings of interest. The result was a thousand-to-one ineffeciency in the use of the packet channel. We were disappointed in the absence of any search, max, min, rate, or threshold comparison commands in the KTU to help identify high or low readings of interest prior to transmission. Secondly, there was no way to remotely select the KTU. The KTU must have a dedicated TNC or a human operator to manually switch it into the circuit. For these reasons, we found the KTU to be of no value as a remote telemetry unit in this application.

HISTOGRAM OF BEACONS PER HOUR for 07-26-92. **(Usually transmitting 6** per hour)
SSID **shows assigned frequency of operation for that unit.**

Time(EDT)	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	23	22	21	20	19	18	17
LANTA-6	.	.	1?	2	3	2?	4	4	.	4	.	.	.	.	1	.	1.	1	1	1	.2	.	.
LANTA-12	.	1	1	2	3	2	5	3	2	3	2	.	.	.	.	1	.	.	2	4	1	3	.
LANTA-4	3	1	.	.	2[1]	1	2	1	3 ?.	.	.	.	.	1?13.	.	.	.	.	3	.	.	.	3
OCEAN-6	1	2	1	2	2	1	2	1	2	2	2	2	1	2	1	2	2	2	2	2	2	2	2
LANTB-6	4	1	4	2	3	3	5	4	2	2	.	.	1	2	.	1	1	1	1	2	3	2	2
LANTB-12	2	4	5	6	1434	6	.6	6	6.	3	..	.	2.	2.	.	.	1	9	.6	5	5	2	3
	.	.	.	.			.	.											.	3	.	.	.
BRMUDA-6	4	6	2	2	6	3	1	2	.	.	.	.	.	.	.	.	.	.	1	.	1	1	2
NEWENG-6	3'	4	3	6	6	5	3	2	.	.	.	.	.	.	.	.	.	.	.	1	.	3	.

NOTES: LANTA **arrived NY this morning.** LANTB **arrived** Newport RI **last** night, Sailboats enroute up **Deleware coast and into** Deleware Bay.

Figure 3 Statistics on the number of **beacons received per hour from each unit over the last** 24 **hours are available to system users with a single keystroke.**

OPERATIONS

Beacons from the **deployed** boats are automatic as **long as the packet** terminal is on and the **radios are properly configured.** The crews are encouraged to update their beacons once a watch every four hours or whenever significant changes occur. **Similarly,** the crews are encouraged to watch for beacons from the master station and to check in at least twice a day when conditions are favorable. Each squadron has three boats equipped with packet, one on each of the three HF frequencies at 4, 6 and 12 MHz to take advantage of frequency diversity. The system software accumulates statistics on the number of beacons received from each unit per hour and makes that information available to users as shown in figure 3. Throughout the summer on HF, 40 percent of all beacons were received within the first ten minutes, 80 percent within the first hour, and 90 percent within 4 hours as shown in figure 4.

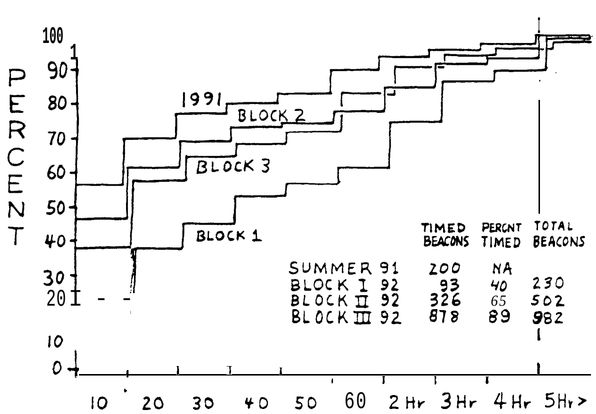


Figure 4. ELAPSED TIME BEFORE RECEIPT

RESULTS

Although the Naval Academy system was only experimental the first summer with three boats, more than 400 messages were exchanged over the system and 200 position reports were logged. Communication success measured by the number of successful communication events per four-hour period with packet approached 83% compared to about 20% for the twice per day HF voice system used before. The success of the HF beacons and our very low priority on gaining Navy UHF satellite time, showed the advantage of having a fully integrated HF system as part of the UHF satellite AX.115 network.

By the second year with ten boats configured for packet, there were always three boats per squadron able to monitor the three different HF frequencies for frequency diversity. Over 600 messages and 1700 position reports were logged. Further, the tactical display software transformed the system from an interesting experiment to a useful and productive tool in time for most of the summer of 1992.

AUTOMATIC NAVIGATION-TO-TNC INTERFACE

A highlight of the summer was the three week cruise of the one boat that is configured as an oceanographic research vessel. With GPS and several computers on board, a serial port was dedicated to send a new GPS position report beacon text to the TNC every ten minutes. At a cruise speed of 10 knots, this resulted in a fresh position report accurate to about 50 feet every two miles during a 300 mile cruise, A replay of the positions of this boat are shown in figure 5. This fall, we will be working on a direct interface between a GPS receiver and the TNC without any need for the computer.

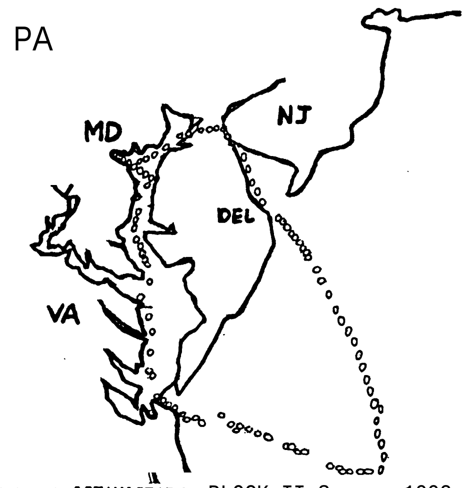


Figure 5 A plot of the 3 **week track history of the one unit equipped with an interface to a** GPS **receiver to provide an automatic** fresh position **into the** TNC **beacon text every 10 minutes.**

The National Marine Electronics Association (NMEA) 0183 standard defines a 4800 baud serial data **position reporting** format for interfacing **commercial navigation equipment. By simply programming a TNC for 4800 baud and placing it in the UNPROTO CONVERSE mode, nothing else is needed for AX.25 position reporting via radio as shown in figure 6. Unfortunately, however, there are two problems which must be resolved** before **this connection is viable.**

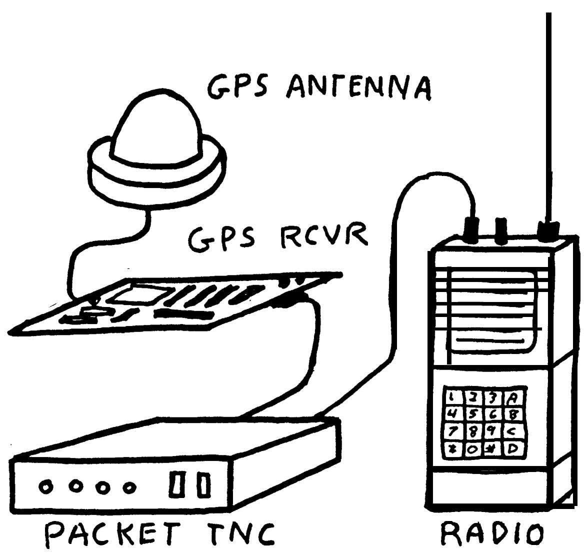


Figure 6. **A complete automatic position** reporting system can **be assembled using a GPS receiver interfaced to a radio using an AX.25 packet radio TNC.**

First, the NMEA 0183 interfaces on all GPS receivers we studied repeat a series of over a dozen lines of navigation **data at a period of once every 2 seconds or so. We only need the one line** which contains **LAT/LONG; and we only need it** once every **10 minutes or so.** Manufacturers need to **provide a** user programmable periodicity for **their existing** formats. One company, **MAGELLIAN, makes a GPS receiver prototyping kit ($550) which implements a user definable periodicity from 1 second to 5 minutes, which is useable for AX.25 applications.**

Second, the standard TAPR-2 TNC does not include a provision for powering up in the UNPROTO-CONVERSE mode (the PK-232 does). Without this power up feature, a terminal and human operator, or PC, is also required **to place the** TNC in UNPROTO-CONVERSE mode with the "conv" command. We are proposing to the TNC manufacturers to provide a power up UNPROTO-CONVERSE mode **as follows:**

UNUP (ON/OFF) - UNPROTO CONVERSE on Power **UP**
- **ON - The** TNC **will power up in** UNPRO-CONV **mode. From then**, all **operations are normal, ie: a ctrl-C will return you to command mode.**
- **OFF - Default setting. Normal** TNC modes.

UNPERM (ON/OFF) - UNPROTO-CONVERSE PERMANENT
- ON **-** Same **as UNUP except that the** TNC, if **left in** cmd: **mode will always** revert **back** to UNPROTO-CONVERSE **after a set time period. That** time period is set using the existing CHECK parameter.
- OFF **- Default setting.** Normal TNC modes.

Once these two problems are resolved, automatic vehicle location using AX.25 can be **implemented at a surprisingly low cost, by simply plugging in a navigation device to your existing mobile packet** system. LORAN-C **devices with** NMEA-0183 interfaces can be **purchased for under $400 from any Marine** Electronics store. **GPS** receivers **are not** far behind at around **$900 and** falling **rapidly!** At least one LORAN receiver, the NORTHSTAR 800 already has the mods noted above. Unfortunately, however, we cannot use LORAN **at** the Naval Academy because we are **located** only 1 mile from the US NAVY **Megawatt** VLF transmitting **station** which wipes out LORAN **for about** 20 miles around us.

Even without the two modifications noted above, automatic vehicle location is still very easy to implement using a simple PC **program between the navigation** device and TNC to properly configure each device at power up, and to **reduce** the NMEA-0183 reporting periodicity to something reasonable for the radio channel. Still, the cost of implementing automatic vehicle location via AX.25 for under $600 **is far** less than the cost of commercial systems which have been under development for over **20 years.**

AUTOMATED POSITION REPORTING SYSTEM (APRS)

The tactical display software used in the Naval Academy application could be very useful in other packet radio networks, especially in support of emergency and disaster communications, or for tracking recreational vehicles, mobile HF'ers, or offshore boaters. There is even an air traffic control net on 14,278 KHz which could use it to track air contacts. A single VHF frequency could be used to track all local boaters in the Chesapeake Bay.

In current AX.25 packet radio networks, the Monitor Heard log in each TNC is the only function which provides realtime information about activity on the network. This information only identifies the most recent callsigns and when they were last heard. The APR software which evolved from the Academy network is a dramatic improvement on this concept, as it displays all callsigns geographically when heard. Different colors show activity on different frequencies. A glance at the screen shows which stations are currently active. Lines can be drawn between pairs of connected stations including all intermediate links. In this way, geographically correct network charts just appear on the screen after monitoring the channel for only a few minutes of heavy use.

The key to this system, of course, is knowledge of every station's geographical position. Using beacons, as we have done at the Naval Academy, is the mechanism. Periodic beacons are not required for fixed stations. In fact, as more and more stations run this software and collect position reports from cooperative stations, a community file of station locations can be assembled and distributed via BBS files! If the idea cought on, BBS's could actually monitor beacons and collect and maintain the position files. Local stations need only update their position data when they move or go portable! Then, only one properly formatted beacon need be transmitted successfully for the community to grab your change in status.

Going back to the monitor heard logs, TNC firmware could be modified to save the text of the latest beacon from each station as well as the time of receipt. A new TNC command would give the owner the option of collecting only beacons and beacon text in his MH log, or not.

APR SYSTEM BEACON FORMATS

Since there are many different applications for this position reporting system, the APR software recognizes several formats of position and status reporting. Table 7 shows the basic formats which include provisions for both automatic and manual reporting in several coordinate systems. Each field in these formats is fixed length except for the status and comment field which is used to report a variety of status attributes.

TABLE 7. BEACON REPORTING FORMATS

Each field is fixed length except for the status and comments. The examples represent a beacon transmitted at 1450 on the 29th day of the month at a position of 38 degrees 45.54 minutes North, 76 degrees 29.43 minutes West, on a course of 038 degrees at 13 knots on a frequency of 145.05 MHz. The status characters indicate that the station is an ARES member with emergency power operating marine mobile capable of operating on all HF bands, plus mode A satellite, with all mode capability on 2 meters and 70 cm FM. He can also operate RTTY, ATV and Marine VHF. The definition of these status characters are given on the next page.

MOBILE PLATFORM WITH COMMENTS: **Day,time,lat,long,course,speed,status**
```
@291450/+3845.5/-07629.4/038/013\SAEh*nS1U2V4W/comments to end of line
```

NMEA-0183 LORAN/GPS INTERFACE: **Identifier,latitude,longitude**
```
$GPGLL 3845.54,N,07629.43,W    (from a GPS device)
$LCGLL 3845.54,N,07629.43,W    (from a LORAN-C device)
```

FIXED STATION INITIAL REPORT: **Latitude,longitude,frequency,status,comments**
```
#+3845.5/-07629.4/145050\SAEh*nS1U2V4W\comments to end of line
```

FIXED STATION UPDATE: **frequency,status,comments**
```
&145050\SAEh*nS1U2V4W/comments
```

N-S-E-W REFERENCE: **Day,time,N/S** and E/W offsets from reference **point**
```
$M291450/+06.3/-38.7/Baltimore\SAEh*nS1U2V4W\comments (in Nautical Miles)
$K291450/+10.8/-34.2/Annapolis\SAEh*nS1U2V4W\comments (in Kilometers)
```

STATUS FORMAT DEFINITIONS

The status block is a variable length character block which begins with a backslash (\) and goes to the end of the beacon. It contains a collection of alpha-numeric characters each of which represents a special attribute. The first character defines which table of definitions will be used for the attributes and the remaining characters represent the data. The first table that I have defined is the station (S) table for representing station information. Up to 60 additional status tables may be defined using the upper and lower case letters and numerals. Only the numerals are position dependent and are used to amplify other categories such as for H, h, U, V, or s. In this table, U distinguishes all-mode capability from V which assumes FM. General comments may be included at the end of the block following a slash (/) character.

Table Name: STATION ATTRIBUTES
Table identification character: S

A - ARES	a - aeronautical
B - Beams	b - battery pwr
C - CAP	c - cw
D - DX	d - digipeater
E - Emer-power	e - EMT trained
F - Field Portable	f - foxhunter
G - Generator	g - gps equip
H - HF with linear	h - hf other
I - Intl Marine VHF	i - inmotion
J - TBD	j - TBD
K - APLINK	k - TBD
L - Landline modem	l - loran equip
M - MARS	m - mobile
N - Node	n - nautical/marine
O - AMTOR	o - optical
P - PBBS	p - phonepatch
Q - ARRL mbr (QST)	q - cq
R - Races	r - repeater
S - Satellite	s - sstv
T - TCP-IP	t - rtty
U - USB,LSB & CW	u - microcomputer
V - VHF	v - ATV (FSTV)
W - Wx/Marine band	w - weather equip
X - 10 GHz and up	x - fax
Y - TBD	y - TBD
Z - TBD	z - TBD

1 -160 meters	1 - 50 MHz	1 - Mode A
2 - 80 meters	2 - 144	2 - Mode B
3 - 40 meters	3 - 220	3 - Mode J
4 - 30 meters	4 - 440	4 - Mode L
5 20 meters	5 - 902	5 - Mode S
6 - 18 meters	6 - 1296	6 - TBD
7 - 15 meters	7 - 2250	7 - UOSAT
8 - 12 meters	8 - 3230	8 - PACSAT
9 - 11 meters	9 - 5650	9 - 9600 ax25
0 - 10 meters	0 - scanner	0 - 1200 ax25
* - All/most	* - All/most	* - All/most

A second table of definitions for emergency and disaster communications is suggested below: ALthough the (S)tation table shown above is reasonably complete, the Emergency table is only offered as an example. I hope the experts in the field of emergency communications such as ARES and RACES will take it upon themselves to establish and maintain their own definitions.

Table Name: Emergency operations
Table identification character: E

A - ARES	a - ambulance
B - BEDS # follows	b - bilogical teams
C - CAP	c - city
D - Doctor	d - disaster team
E - Emer-power	e - EMT trained
F - Fire station	f - food
G - Generator	g - government (fed)
H - Hospital	h - helo
I - Intl Marine VHF	i - inmotion
J - TBD	j - TBD
K - TBD	k - TBD
L - Landline modem	l - loran
M - MARS (military)	m - mobile
N - Nuclear equip	n - nautical/marine
O - AMTOR	o - oil spill equip
P - Police	p - phonepatch
Q - Headquarters	q - freQs #'s follow
R - Races	r - RedCross
S - Shock-trauma	s - state
T - TV/radio/press	t - triage
U - Utility	u - microcomputer
V - Video ATV	v - vehicles # follow
W - Weather station	w - water
X - Xray capability	x - fax
Y - TBD	y - countY
Z - TBD	z - TBD

1 - 144 MHz	1 - Ladder truck
2 - 220 MHz	2 - Pumper truck
3 - Scanner	3 - Hazardous material
4 - 440 MHz	4 - Ambulance
5 - HF	5 - water truck
6 - Marine VHF	6 - bus
7 - Other govt	7 - Earth moving
8 - Cellular	8 - communications
9 - wormhole	9 - food delivery
0 - CB	0 -

SUMMARY

The purpose of this article is to use the example of the Naval Academy AX.25 packet radio network to show the value and capabilities of a system which includes position and status information in packet beacons. The extension of this capability into other AX.25 packet radio networks could have many benefits. A previous article on the subject of position and status reporting in packet radio networks appeared in the February 1991 issue of Gateway. I intended to evolve the APR software from the Naval Academy software, but by the end of this summer's intensive use, there were enough lessons learned to require a significant re-write before the system could be extended to world wide use. The Latitude and Longitude fields needed to be extended for whole Earth coverage, and the time fields needed to be extended beyond 24 hours to include the day as well. Also, provision for other beacon reporting formats including the NMEA 0183 format was required. Other formats tailored to specific applications, such as emergency operations and statute mile position references were suggested in the earlier Gateway article and are included here. I must emphasize that APR software for the general AX.25 community is NOT YET COMPLETE. As I reorganize the formats of the Academy System for next summer, however, the necessary changes will be included for a more general application.