P1.16   UPGRADE AND TECHNOLOGY TRANSFER OF THE SAN FRANCISCO MARINE STRATUS FORECAST SYSTEM TO THE NATIONAL WEATHER SERVICE[†]

Chuck Ivaldi*
David A. Clark
Massachusetts Institute of Technology Lincoln Laboratory
Lexington, MA

David Reynolds
NOAA/NWS
Monterey, CA

1.   INTRODUCTION

The local airspace surrounding the San Francisco International Airport (SFO) is prone to regular occurrences of low ceiling conditions from May through October due to the intrusion of marine stratus along the Pacific coast. The low cloud conditions prohibit dual parallel landings of aircraft to the airport's closely spaced parallel runways, thus effectively reducing the arrival capacity by a factor of two. The behavior of marine stratus evolves on a daily cycle, filling the San Francisco Bay region overnight, and dissipating during the morning. Often the low ceiling conditions persist throughout the morning hours and interfere with the high rate of air traffic scheduled into SFO from mid-morning to early afternoon. The result is a substantial number of delayed flights into the airport and a negative impact on the National Air Space (NAS). Air traffic managers face a continual challenge of anticipating available operating capacity so that the demand of incoming planes can be metered to match the availability of arrival slots.

2.   HISTORICAL BACKGROUND

In 1995 the FAA's Aviation Weather Research Program (AWRP) launched a "Marine Stratus Initiative", whose objective was to improve ceiling and visibility forecast guidance for more reliable anticipation of available operating capacity at SFO.   MIT Lincoln Laboratory served as technical lead for the

project, in collaboration with San Jose State University (SJSU), the University of Quebec at Montreal, and the National Weather Service (NWS) Central Weather Service Unit (CWSU) at the Air Route Traffic Control Center (ARTCC) in Fremont, CA (also known as Oakland Center). The project led to the development of the Marine Stratus Forecast System (Clark and Wilson, 1996).   An important element of the system is the generation of automated objective forecast guidance. This guidance is used by forecasters in making their recommendation to air traffic managers regarding the timing of cloud dissipation that will allow dual independent aircraft approaches. The guidance is presented to system users in the form of a "consensus forecast" derived from four independent component forecasts.   In addition to providing a deterministic forecast of the best estimate of transition time to dual approaches, the consensus forecast is also converted to a probabilistic representation showing the likelihood of dual approach availability at specific target forecasts times during the period of highest arrival traffic demand (Clark et al., 2005).

During the early years of development, efforts were focused on the creation of a suitable database of relevant and routinely available weather observations for use in forecast model development. Following discussions with the local aviation forecasting community and in particular, the CWSU at Oakland Center, it was determined that additional specialized sensors would be required in the vicinity of the approach zone into SFO to help characterize the phenomenology of low cloud conditions. Two sensor sites were established, one at SFO and the other at San Carlos Airport (SQL), just to the south of the approach zone.   The geographical configuration of sensors that were installed is shown in Figure 1. Each site includes a Sonic Detection and Range (SODAR) instrument to estimate cloud top height, a pyranometer to measure incoming solar radiation, and instrumentation to provide high temporal resolution measurements of temperature, humidity, and wind.   Most of the remaining

*Corresponding author address: Chuck Ivaldi, MIT Lincoln Laboratory, 244 Wood Street, Lexington, MA 02420-9185; e-mail: ivaldi@ll.mit.edu

observations are acquired from the standard suite of weather observations made widely available by NWS. They include hourly surface observations of standard meteorological parameters, twice daily vertical measurements from the balloon-borne rawinsonde launched from Oakland, and 15-minute satellite data from GOES-10. There are two additional key data sources of note that provide additional data for display and as input to some of the forecast models. One is the FAA-maintained instrumented site located at the San Mateo Bridge (black dot in Figure 1), situated directly below the primary runway approach zone into SFO. The ceilometer sensor at this site provides 5-minute cloud amount and cloud base height measurements used operationally in assessing the availability of visible approaches into SFO. The second data source is 15-minute surface observations that are acquired from the Automated Surface Observing System (ASOS) station located at SFO (yellow dot in Figure 1).

The collection and processing of field site and conventional data was performed by a UNIX workstation (known as the base station) located within the meteorology department at SJSU. As collaborators on the project, SJSU personnel had participated in the installation of field site equipment and were responsible for continued operations and maintenance support, so it was a

natural extension to house the workstation at SJSU to facilitate O&M tasks. To make the observation data collected by the workstation available for viewing at the CWSU, a dedicated digital data line was installed so that display products hosted on the workstation at SJSU could be accessed from a web browser running on a UNIX workstation at the CWSU.

Figure 2 is a depiction of the system configuration, as it existed during the years that forecast demonstrations were conducted (2001-2003). The base station collected field site data using the Kermit protocol over a dial-up phone connection. A separate phone line was available for automatic and manual teleboot operations to reset malfunctioning field site hardware connected to a remote teleboot device. Automated surface observations from the ASOS site at SFO were also obtained through a dial-up phone connection, while soundings, hourly surface observations, and satellite data were obtained via an Internet connection provided by the SJSU campus server. Raw observations from the site at the San Mateo Bridge entered the system at the display workstation located at the CWSU. From there, the data were transferred for further processing to the base station via the digital line linking the two systems. The base station computer was also connected to a teleboot device to allow a remote reset of the hardware in cases of a hung or otherwise unresponsive system.
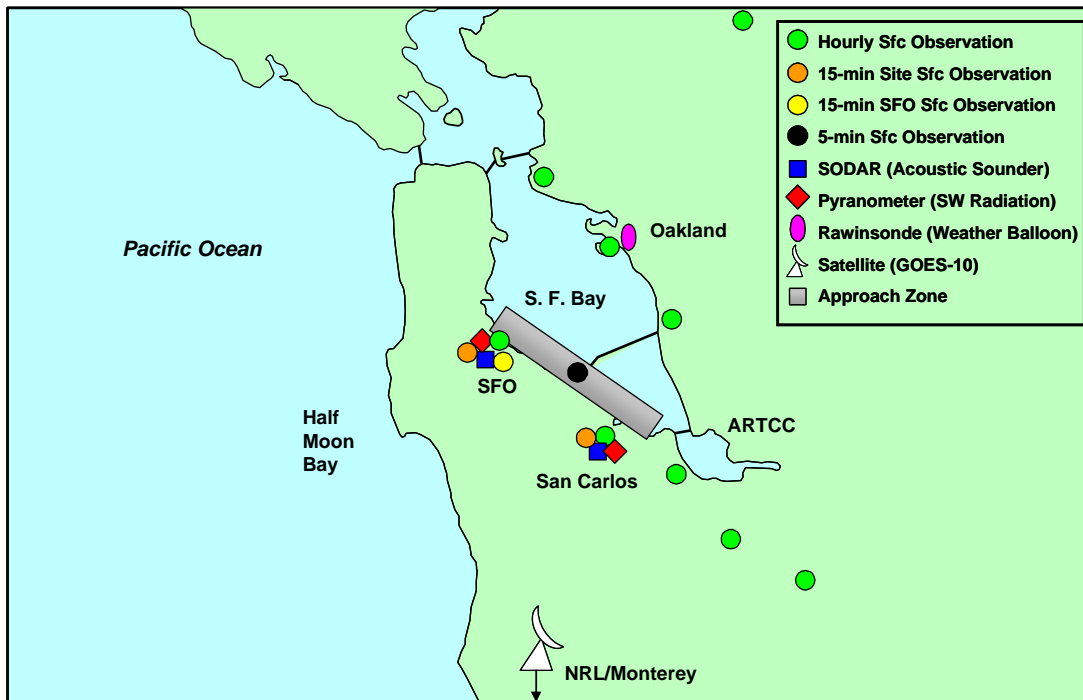

Figure 1. Geographical sensor configuration for the Marine Stratus Forecast System.
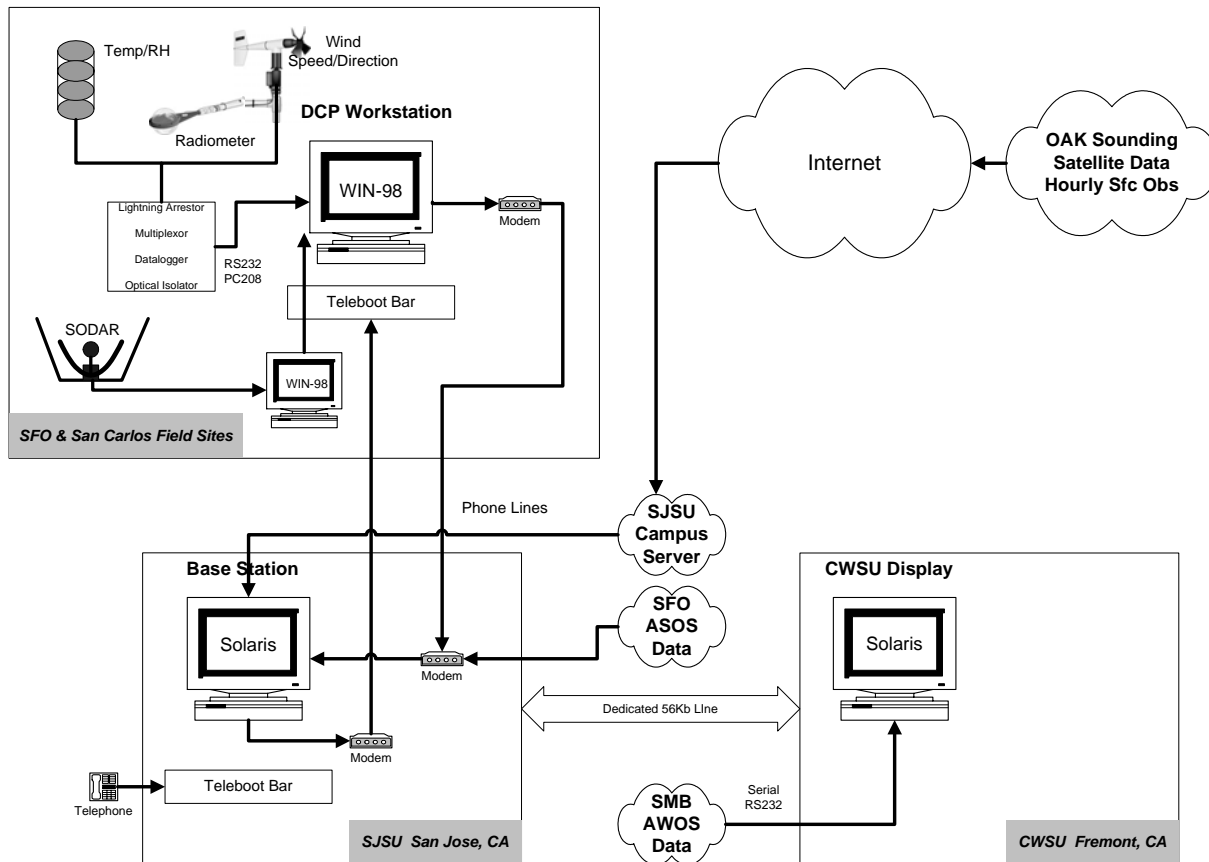
Figure 2. Hardware configuration of the prototype SFO Marine Stratus Forecast system.

Once the field sites, base station computer, and display computer were in place and the software to acquire and process the data had been developed, display products were generated to deliver the weather observations to the CWSU. In parallel with display product generation was forecast model development. In 2001, the first iteration of forecast models was ready for operational demonstration. The display system was expanded to include presentation of the forecast output, and to deliver the observations and forecasts to a more general audience via the Internet. This initial demonstration ran through the summer months of 2001. This initial operational exposure led to streamlining and automation of the model development process and a modification of the models in preparation for a follow-up demonstration during the 2002 stratus season. This iterative process of test and development was repeated during the summer of 2003. An example of the display interface showing observations and numerical forecast guidance for a day during the 2003 demonstration season is shown in Figure 3.

3. TECHNOLOGY TRANSFER INITIATIVE

In the spring of 2003, representatives from the FAA, CWSU at Oakland Center, NWS Office of Science and Technology, NWS Western Region, National Center for Atmospheric Research (NCAR), and MIT Lincoln Laboratory met to initiate discussions of a follow-on plan in which NWS would assume responsibility for the operations and maintenance of the system. Out of this meeting, recommendations were made to have the National Weather Service Forecast Office (NWSFO) in Monterey take the lead in pursuing the effort and to use the 2003 demonstration season to 1) further evaluate the contribution of the forecast model guidance in improving the operational forecasts, and 2) obtain a more detailed assessment of the level of effort, skill, and cost required to maintain the system on an annual basis. In a subsequent gathering held during the midseason technical interchange meeting in August, a plan among representative organizations was solidified. Under the plan, NWS agreed to assume responsibility for operation and maintenance of the system under a multi-year confirmatory phase provided the system was

upgraded to meet requirements that would bring the system to an acceptable level of reliability and performance. The agreement contained the following elements:

1) Transfer of ownership of existing field site equipment to NWS.

2) NWS to procure new equipment for the upgrade:
   a. Field site hardware and spares.
   b. Base station and display workstations.
   c. Upgrade data communications services and security.
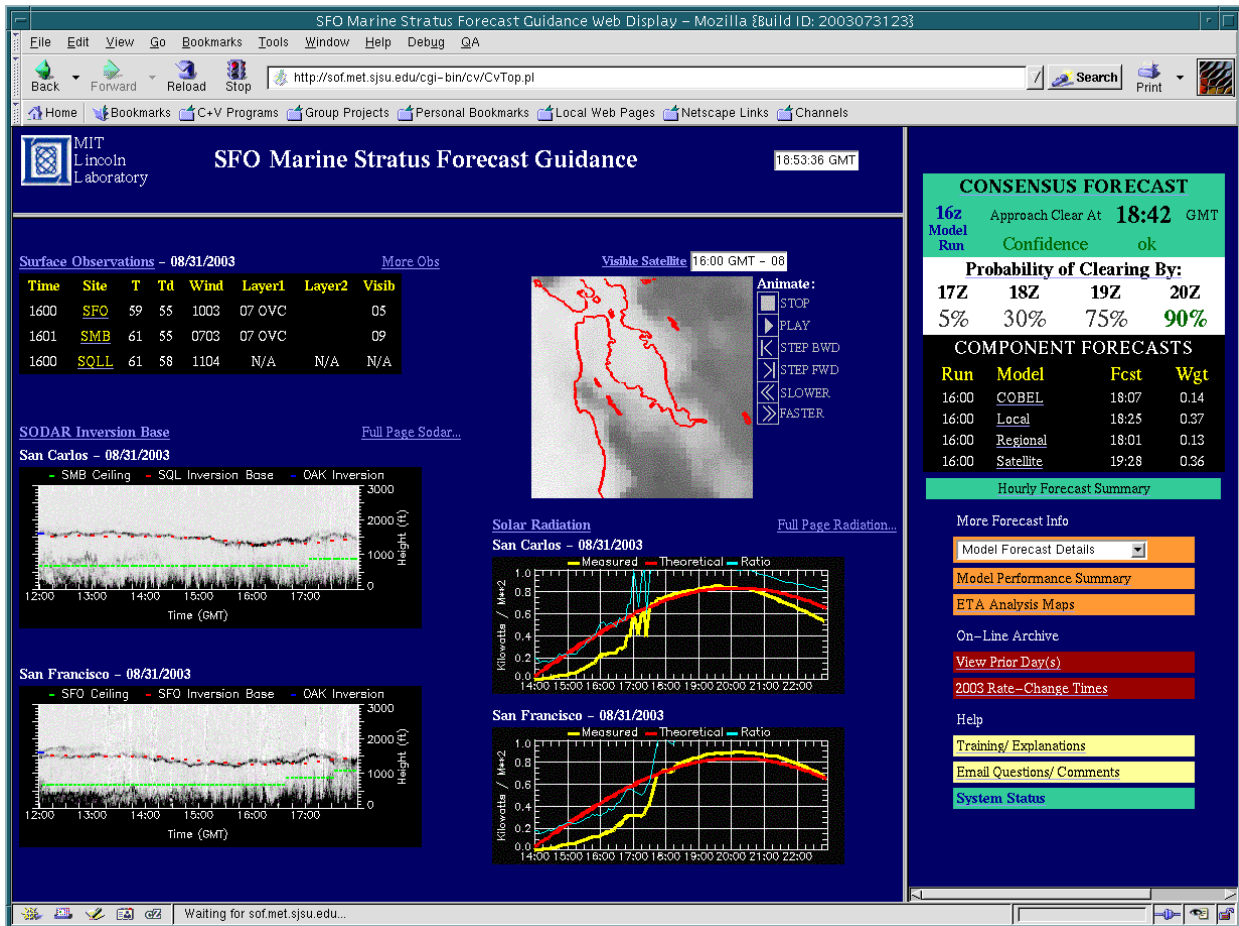
Figure 3. Prototype system display interface. The left frame of the display contains field site observations of surface conditions, the SODAR return, and radiation trace for each field site. Surface conditions for stations in and around San Francisco Bay are available via a pop-up window. The top section of the right frame contains the current deterministic consensus forecast as well as a table that provides the probability of clearing at times that coincide with peak arrival traffic demand. Deterministic component forecasts used to derive the consensus forecast appear just below. Buttons also allow one to retrieve a summary of current forecasts issued for the day and more detailed information about each forecast. Further down the frame, one can review real time forecast performance statistics, examine observations and forecasts from any prior days of the current or past seasons, and view the current season official rate changes that serve as verification for the forecasts. Online help is accessible via a button at the bottom of the page.

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3) Relocate the base station computer from SJSU to the CWSU at Oakland Center.
4) Field site maintenance to be performed by NWS.
5) Establish field site agreements between NWS and airport authorities at San Francisco and San Carlos Airports.
6) Delivery of a system description/maintenance document and updates to online help.
7) System training to be performed during installations at the field sites and at the CWSU at Oakland Center.
8) Ability to extend the confirmatory phase if needed.

3.1 System Requirements

Personnel from NWSFO/Monterey and SJSU conducted field site visits during the fall of 2003 to assess the condition and existing configuration of site hardware. NWSFO/Monterey concluded that in order for NWS to support the operation and maintenance of the field sites, the following changes were necessary:

1) Procure a rack-mounted SODAR system built by a single vendor.
2) Provide the ability to remove and replace major components found to be defective with vendor-supplied spares.
3) Provide full documentation of SODAR hardware and data flow to troubleshoot problems.
4) Provide a service to ship defective components to the vendor for repair.
5) Refurbish and re-calibrate temperature, humidity, and radiation sensors.
6) Purchase spare parts for SODAR system and sensors.
7) Consolidate surface meteorological data collection, SODAR data collection and noise suppression, and data communications functions onto one computer (the prototype system utilized two computers).
8) Procure three identical weather-tight equipment boxes (one as a spare), each designed to house a lightning arrestor, multiplexor, datalogger, and optical isolator.

Upgrading the communications services was driven by the need to reduce costs and to increase reliability and extensibility of the data communications infrastructure. The prototype system had been developed during the mid 1990's, at a time when high-speed services such as Digital Subscriber Line (DSL) were not available. The prototype system utilized phone lines and dialup service to acquire data from the field sites with one phone line dedicated to data transfer and a second line utilized for teleboot operations. Although the configuration worked reasonably well, it was expensive to maintain. In the upgrade plan, the field sites and base station would be configured with shared DSL service, utilizing the Internet as the primary means for communicating field site data to the base station. Dial-up phone service would be used as a backup to Internet-based retrievals and for telebooting. At the time, the switch to DSL was estimated to provide a cost savings of approximately $5K per year.

In the technology transfer plan, the base station would be relocated to the CWSU at Oakland Center to simplify communications with the display computer and to facilitate access by NWS personnel conducting O&M tasks. Requirements for the new base station included the ability to ingest data directly from the AWOS feed located within the confines of the CWSU work area, the ability to backup system and project software and data, and changeover to the LINUX operating system to comply with NWS regulations for open systems.

3.2 Field Site Specifications

Based on the requirements previously outlined, NWS contracted with the National Oceanic and Atmospheric Administration's Environmental Technology Laboratory (NOAA/ETL) to build and install two SODAR systems, replacing the existing two prototype systems utilized during the research and development phase of the project. Elements of the contract included:

1) Stabilize the SODAR design to meet NWS requirements
2) Procure the necessary parts to build and test two complete SODAR systems.
3) Deliver O&M-level documentation.
4) Deploy the two SODAR systems at the field sites.
5) Procure a set of spare parts.
6) Implement improved aircraft noise suppression and recovery software.

NWS also contracted services for the remaining field site equipment. New equipment would be shipped to the field sites and assembled by NWS

and SJSU personnel. Elements of that contract included:

1) Provide a new pyranometer and anemometer to be used as spares.
2) Recalibrate existing temperature and humidity sensors and one pyranometer.
3) Assemble and test a new spare equipment box containing lightning arrestor, multiplexor, datalogger, and optical isolator.
4) Upgrade the equipment box and lightning arrestor at the San Carlos site.
5) Provide a new lightning arrestor at the SFO site.

3.3 Base Station and Display Workstation Specifications

In the winter of 2003-2004, NWS purchased the new base station and display workstation. The salient characteristics of each are summarized in Table 1. At the end of March 2004, while the display workstation remained behind to be configured by NWS, the base station was shipped to MIT/LL so that personnel could install the operating system, setup user and ftp accounts, and to install and test hardened (and in some cases ported) software from the Marine Stratus Forecast System. The system was tested using copied live files that were still being gathered by the prototype base station to drive data post processing and forecast model activation on the target system. In late May, the configured base station was shipped back to NWSFO/Monterey for deployment to the CWSU at Oakland Center in early June 2004.

3.4 Implementation Effort

In early May 2004 shared DSL service was installed at the SFO site and data transfer tests were conducted between the site and the base station at SJSU prior to the upgrade. By the end of May, DSL service was also ready at the San Carlos field site. The installation plan called for NWS personnel to participate in the installations at both field sites as well as at Oakland Center, so the SFO site was targeted first during the beginning of the week of June 7th, followed by the San Carlos site two days later and finally Oakland Center. The field site upgrades included installations of the new SODAR systems, refurbished surface meteorological sensors, equipment boxes, uninterruptible power

supplies, firewall hardware and teleboot devices. The upgrade at Oakland Center included installation of the new base station, display workstation, modems for fall back dialup service and remote teleboot, firewall/hub hardware, teleboot device, and reconfiguration of the AWOS serial feed. Testing continued over the course of the next few weeks, revealing a defect in SODAR data processing that was corrected with a software patch. On June 29th, operations officially resumed in support of the 2004 stratus season with an announcement to government and private sector interests.

Figure 4 is a depiction of the hardware configuration for the Marine Stratus Forecast System as a result of the upgrade and Table 2 summarizes the data used by the system. The system encompasses three locales: the two original field sites equipped with identical hardware and software, and a two-node local area network (LAN) housed within the CWSU at Oakland Center. The LAN is composed of the base station computer and display computer. The base station acquires data from both the field sites and other sources using a commercial DSL connection to the Internet. A backup means to acquire field site data is available if needed, using a dialup Point to Point Protocol (PPP) connection over a phone line that is shared with DSL. The dialup connection is shown in Figure 4 as the dashed line connecting field site modems to the base station modem. Five-minute ASOS surface observations for SFO are acquired through a dialup connection using the Kermit protocol. Five-minute AWOS surface observations from the San Mateo Bridge site enter the base station via a serial RS232 line. NWSFO/Monterey provides the Oakland upper-air sounding and hourly surface observations from stations in and around San Francisco Bay and satellite data are retrieved from the Naval Research Laboratory (NRL), also located in Monterey. These data sources are acquired using the DSL connection to the Internet.

Field site instrumentation, including temperature and humidity sensors, a pyranometer, and wind sensor, are tower mounted and connected to a data logger that prepares the sensor data for acquisition by the Data Collection Platform (DCP), a PC running the Windows XP operating system. The DCP also collects and processes data from the SODAR system.

Both the field sites and the LAN at the CWSU are protected from Internet intrusion through inclusion of a firewall device. The firewall is configurable through a user interface to allow only permitted inbound traffic for remote login. The firewall does not limit outbound access. At the CWSU, the firewall also acts as the LAN hub.

Finally, all three locations are configured with teleboot bars. A teleboot bar allows a user or a computer to dial into the device and cycle power to any device attached to the bar. In Figure 4, a dedicated modem at the CWSU provides the base station with the ability to dial into either field site and clear a malfunctioning device without a person-in-the-loop. A teleboot bar is also located at the CWSU to provide maintenance personnel the ability to dial in to the CWSU and reboot the base station or communications equipment.

A more detailed description of the upgraded system can be found in the system documentation report (Clark et al., 2005).

Table 1.
Computer specifications of the upgraded system

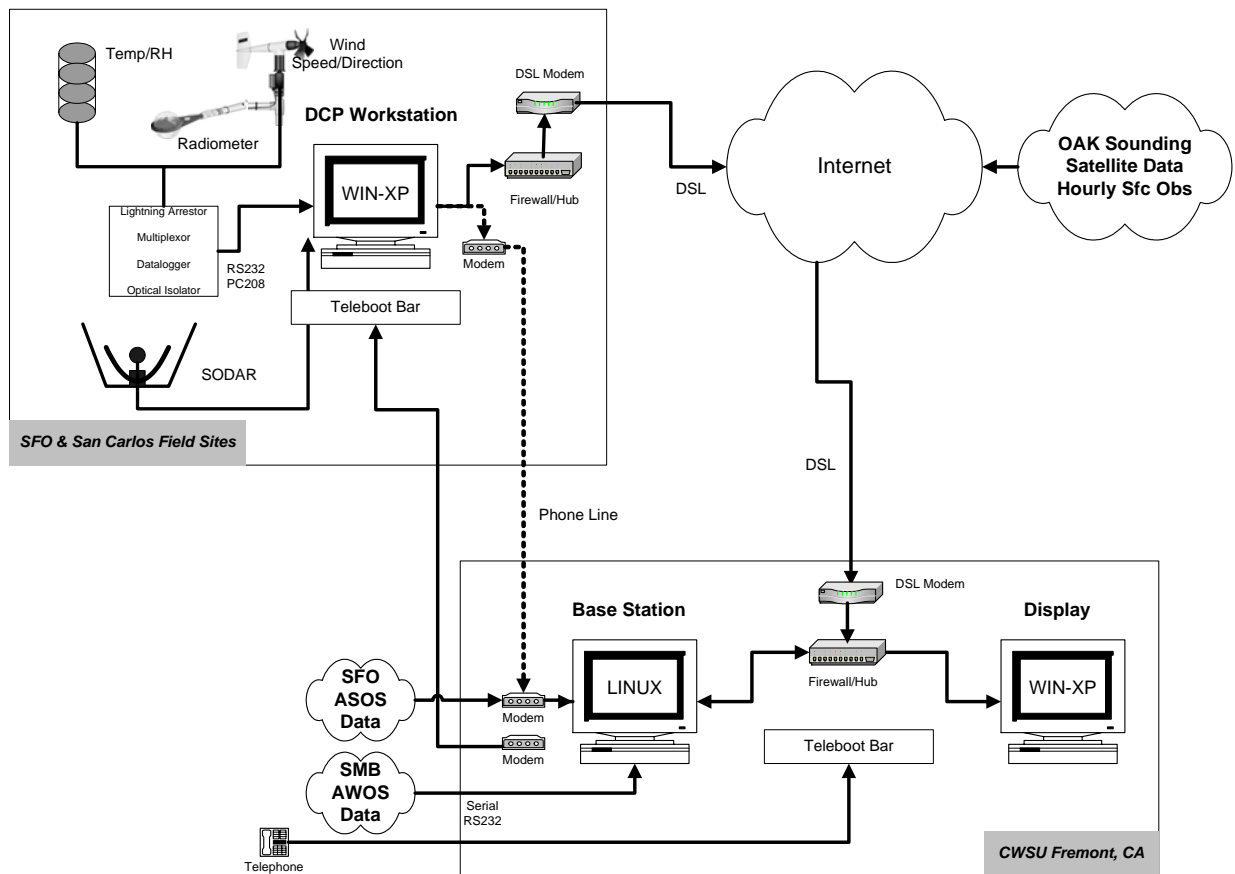|	Base Station	Display Workstation/Site Computers
Model	Dell PowerEdge 400SC	Dell Precision Workstation 360
Processor	Pentium 4 @ 2.8GHz	Pentium 4 @ 2.4GHz
Memory Capacity	1GB	1GB
Disk Capacity	80GB[1]	80GB
CD R/W Drive	Yes	Yes
Number of COM Ports	3	2
Tape Backup	Yes	No
Operating System	Red Hat 9.0 (LINUX)	Windows XP Professional

[1] RAID level 1.

Figure 4. Hardware configuration of the upgraded system.

Table 2.
Data Source Description for the Upgraded System

Data	Temporal Resolution	Description	Acquisition Rate (min)	Origin of Data	Method of Access
SFO ASOS	5-minute	Obs for SFO	15	NWS/San Francisco	Dial-up/kermit
SMB AWOS	5-minute	Obs for SMB	5	ARTCC/Fremont	Direct feed/ readport
SFO Field Site	5-minute	Obs for SFO	15	Field Site at SFO	DSL/Dial-up/ ftp get
		- T, Td, Winds			
		- Radiometer			
SFO Field Site	1-minute	SODAR data	15	Field Site at SFO	DSL/Dial-up/ ftp get
SQL Field Site	5-minute	Obs for SQL	15	Field Site at SQL	DSL/Dial-up/ ftp get
		- T, Td, Winds			
		- Radiometer			
SQL Field Site	1-minute	SODAR data	15	Field Site at SQL	DSL/Dial-up/ ftp get
METAR Obs	Hourly	Obs for selected stations	60	NWSFO – Monterey transfer NWS web sites UNIDATA (See Note 1)	DSL/ftp put DSL/web get DSL/ftp get
OAK RAOB	Twice Daily	OAK Sounding	60	NWSFO – Monterey transfer NWS web sites UNIDATA (See Note 1)	DSL/ftp put DSL/web get DSL/ ftp get
GOES-10	15-minute	Visible imagery	15	NRL/Monterey	DSL/ftp get

[1] Primary and backup sources for data
a) NWS web sites include: www.wrh.noaa.gov (OAK sounding), weather.noaa.gov (Hourly observations)
b) UNIDATA from SJSU

4. PERFORMANCE SUMMARY

The 2004 season marked the final demonstration period and the first season to use the upgraded system. Personnel that had been responsible for operations and maintenance of the prototype system worked with NWS technicians during that time to provide guidance and answer questions in preparation for system hand-over at the conclusion of the season. The 2004 season ran from June 29 to October 14. Consensus and component forecasts were generated for all stratus days during the period. A minor problem was detected early on in which sounding data from Oakland was consistently late, which in turn, prevented one of the component models from generating a forecast in a timely manner. The problem was resolved by including a reliable secondary source for the sounding data in the data acquisition logic as a backup to late postings from the primary source.

On October 15, 2004 NWS switched the system into "Winter Mode", a mode in which observational data continues to be collected and displayed but numerical forecast guidance is not generated. It was during this mode and time of year that NWS conducted maintenance tasks including changes to bring the computers inline with NOAA security policies and movement of equipment at the SFO field site into the new equipment box. On May 15, 2005 NWS resumed summer stratus season mode of operations. In July, the satellite data provider (NRL/Monterey) reduced the number of images available from four times an hour to twice an hour due to processing cycles needed to acquire other satellite data. The impact of this reduction was that the satellite component forecast model was unable to run during hours that the top of the hour satellite image was unavailable. This is normally not an issue as long as substitute data valid at 15 or 45 minutes after the hour is available. In 2005, there were 15 missed opportunities in which the satellite model did not run due to missing substitute data.

The cases were confined to the 15 and 18Z forecast initialization times.

Since 2001, quantitative assessments of forecast guidance performance have been posted on the display interface as a running tally of consensus and component model forecast errors. Included is a static table showing past forecast performance as well as a table that shows the running performance for the current season. This table is automatically updated daily during the stratus season. The minimum acceptable performance (and comparison benchmark) is considered to be "conditional climatology", defined as the forecast error that would result by simply using for a forecast the "average" stratus clearing time at each of the forecast initialization times. A summary of conditional climatology, previous system performance (2003-04) and 2005 season performance (through 19 Sept.) is provided in Table 3. For the pre-dawn hour forecasts, consensus outperforms climatology on average by about 12%, and during the morning hours by about 35% based on data from 2003-2005. During 2005, high confidence morning forecasts provided a 53% improvement.

An additional important aspect provided by the forecast guidance system is its ability to generate automated objective probabilistic forecasts of clearing by key operational target times, namely 17, 18, 19, and 20Z (see top window of the forecast frame of Figure 3). The "reliability" of these probabilities was examined using the system forecasts generated during the 2003-2005 seasons. The results of that analysis are shown in Table 4, with a breakout of performance based on bins in 10% steps from 60 to 99%. Note that for all bins, burn off was predicted correctly 84% of the time. The second half of Table 4 shows that for times stratus did not burn off at the predicted times (17, 18z), how late the burn off was from the target time. Note that for the majority of cases, burn off occurred in less than 30 minutes from the target time.

Table 3.
Consensus model median forecast error in hours:minutes for each forecast initialization hour

	09z	11z	13z	15z	16z	17z	18z
Conditional Climatology[1]	1:03	1:03	1:03	1:00	1:00	0:52	0:45
2003-2004 Demonstration Seasons	0:58	0:53	0:46	0:45	0:40	0:38	0:35
15 May through 19 September 2005 - All	0:55	0:56	0:37	0:38	0:31	0:38	0:43
2005 High Confidence Forecasts Only[2]	0:53	0:54	0:29	0:28	0:29	0:38	0:38

[1] Based on historical data from 1987-2002.
[2] High confidence forecasts as automatically identified by the system in real time. 225 of 364 (62%) total forecasts in 2005 were identified as "high confidence".

Table 4.
Reliability of probabilistic forecasts made during 2003-2005 (through 9/15/05) seasons. Includes all forecasts made prior to 17z, for probabilistic target times of 17z and 18z.

Clearing Probability	# Fcsts	Cleared #	Cleared Pct	Didn't Clear #	Didn't Clear %	Distribution of "late" clearing, Minutes after Target <=30	31-60	61-90	91-120	120-180	181-240
90-99%	144	136	94%	8	6%	7	0	0	0	1	0
80-89%	102	94	92%	8	8%	5	2	0	0	1	0
70-79%	162	128	79%	34	21%	23	7	4	0	0	0
60-69%	132	98	74%	34	26%	23	7	1	1	0	2
All 60-99%	**540**	**456**	**84%**	**84**	**16%**	**58**	**16**	**5**	**1**	**2**	**2**

5. OPERATIONAL IMPACT

The benefit of any decision support system is in improving the operational decisions made by the decision makers. In this case the operational decision to be made is whether to increase the acceptance rate for arrivals at SFO (under conditions favorable to stratus burn off by 18Z) earlier than would have otherwise occurred had the decision support system not been in place. The potential to better match acceptance rates with an anticipated improvement in conditions at SFO also has the benefit of improving the effective use of the NAS, since ground delay programs (GDP) impact en route traffic well beyond the local control center. There are several ways in which output from the system could influence decision making for SFO. The first is to avoid a GDP if ceilings and visibilities are forecast to improve prior to arrival rates exceeding acceptance rates. Second would be to cancel a GDP, once initiated, if confidence was high that clearing would occur prior to the arrival rate exceeding the acceptance rate. A third possibility is to maintain the GDP, but gradually increase the acceptance rate at some agreed upon time prior to clearing, based on the confidence of the forecast.

Each of these decisions carries with it a level of risk. Obviously the first option carries the greatest risk but also the greatest potential benefit to the NAS and the traveler. However if the forecast is wrong, the Oakland Center will be dealing with vectoring many aircraft into a holding pattern and most likely invoking a ground stop. The second option carries with it a reduced benefit, as well as a reduced risk, as less aircraft would be in the air to manage. The third option carries with it even less risk, but also reduced benefit, as it is dependent on the rate at which the acceptance rate is increased prior to clearing.

Prior to the start of the 2003 stratus season, representatives from the CWSU and Traffic Management Unit (TMU) at Oakland Center were briefed by project scientists on (what was then) a new supplemental display that showed the probability of stratus burn off at discrete times that coincided with peak arrival demand. The meeting concluded with an understanding that when the system issued a probability of clearing by 18Z that was 90% or higher, any GDP in place would be cancelled at the time the forecast was made (13, 15, 16 or 17Z). As 2003 was still during the development phase of the research program and the TMU manager had no experience utilizing probabilistic forecast aids, a post analysis of the 2003 season revealed that no documented decisions either not to invoke or to cancel GDPs based on the 90% confidence threshold were in fact ever made. This in spite of the fact that the system has produced 136 forecasts in the three-year period 2003-2005 with a 90% confidence or greater probability of clearing before 17 or 18Z that verified 94% of the time. Of the 8 forecasts that did not verify, 7 had an offset time of less than 30 minutes (see Table 4). Thus there have been missed opportunities to improve the efficiency of the NAS with what were highly reliable forecasts.

After NWS accepted responsibility for management and support of the system and was providing full financial support for the system, an effort was begun to derive a performance measure that could quantify benefits of the system for improving operations at SFO. What was envisioned was running the first two years under NWS management as an exploratory program that would test the hypothesis that the system would improve operations at SFO by a quantifiable statistic: the number of arrivals exceeding the 30 rate (30 aircraft per hour) at SFO prior to a GDP being cancelled. However, as investigations continued, it became apparent that it would be difficult to quantify how much influence numerical forecast guidance has had due to the assimilation of this information into the decision process.

The decision process on whether to initiate a GDP is a collaborative one. Each morning around 1230Z, if a ceiling is in place and a 30 rate has been established for SFO, a conference call is held between the TMU at Oakland Center, FAA at Command Center, an NWS CWSU meteorologist from Oakland Center, an NWS aviation forecaster in Monterey, and representatives from the major airlines serving SFO (as many as five major airlines). The main purpose of the call is to 1) reach a consensus on whether to invoke a GDP and 2) if a GDP is instituted, determine the expected burn off time. Once a burn off time is determined, FAA policy is to add two hours to the burn off time to arrive at a GDP cancellation time. The general guidelines for how operations are conducted at SFO are provided on the following web site:

http://www.fly.faa.gov/ois/west/zoa/sfo/sfo_tm.htm.

These guidelines were recently updated for the ZOA ARTCC by the current TMU manager based on discussions with NWS prior to the beginning of the 2005 stratus season. It was during those

discussions that the TMU manager indicated that a GDP would not be cancelled early. Instead, consideration would be given to adjust the acceptance rate, utilizing the confidence factor provided by the system as well as the consensus forecasts provided by the CWSU at Oakland Center and airline meteorologists.

Note that the above referenced web site specifies that when there is high confidence that burn off is expected by 18Z, the arrival rate will be increased for the last one to two hours of the program. This may be increased to as much as a 45 rate. This will be noted on the GDP, for example as 30/30/45/45 if the program began at 16Z and is expected to be cancelled by 20Z. Note that the policy requires 2 hours be added to the expected burn off time, thus reducing risk of a major vectoring problem for flight controllers. Increasing or decreasing the "miles in trail" can control management of the exact airport arrival rate. For high confidence forecasts, the "6 WEST" plan is invoked. The six control centers impacted by this plan are illustrated graphically in Figure 5. Note that for high confidence forecasts, the eastern one-third of the country is not impacted by a GDP at SFO, making more efficient use of the NAS.
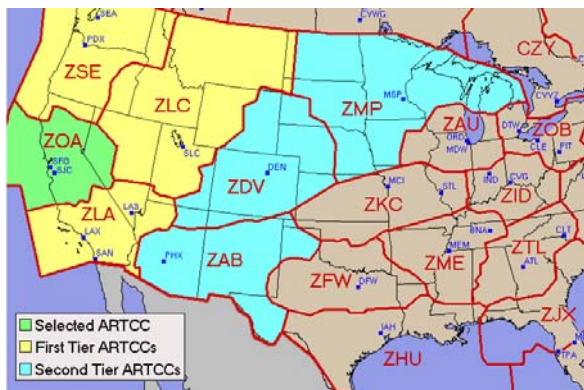

Figure 5. The 6 West grouping for SFO. Comprised of six ARTCCs broken into two tiers, the largest impact of a 6 West GDP is to flights originating from the target ARTCC (green), and to a diminishing extent to flights originating from first tier ARTCCs (yellow) and then second tier ARTCCs (blue).

Although initial efforts have proven difficult in quantifying the contribution of forecast guidance from the system, there does appear to be some positive impact in both SFO and NAS efficiencies through utilization of the system.

6. FUTURE PLANS

During the summer of 2005, the CWSU at Oakland Center began exploring the possibility of examining records from the last three stratus seasons to identify days in which GDPs were established and whether acceptance rates at SFO were adjusted upward prior to the expected burn off. A database of the past three years of GDPs issued for SFO is available from the FAA. The 2002 stratus season has been identified as a baseline to examine GDPs issued prior to the availability of probabilistic forecasts. The seasons 1996 through 2002 were used by MIT/LL to derive and calibrate the probabilities currently used in the system.

To illustrate the two sets of data to be analyzed, two examples are provided. The first is an example of persistent low cloud conditions from September 14, 2005. Figure 6 is a table taken from the system display interface that summarizes the deterministic forecasts and probability tables generated for that day. Note the low probability of burn off by 18Z. A GDP was activated on that day; the advisory that was issued by is shown as Figure 7. Note that the program impacted the CONUS as well as two Canadian airports. A 30 rate was maintained for the duration of the program.

Figure 8 illustrates the second example, a case from July 29, 2005 in which the system predicted a high probability of burn off by 18Z. The corresponding GDP declared for that day, shown in Figure 9, shows a sliding acceptance rate starting with 32 aircraft per hour, valid from 16-17Z, followed by a 40 rate, valid from 17-18Z. It is hypothesized that since the forecast confidence was high, the TMU manager requested the increased acceptance rate during the GDP.

The analysis will be subjective, only suggesting that forecast guidance from the system is having an impact on operations at SFO. However once this analysis is complete and the results are reviewed with the TMU and the airlines, it may provide sufficient insight such that decision makers may be more willing to take a higher risk and avoid or cancel a GDP during high confidence events to improve operations for both SFO and the NAS.

NWS has base line funded this project for the next several years. The very modest cost to maintain and operate the equipment will allow NWS to spend time developing procedures to objectively evaluate the system. Future use of the system as a decision support tool will require convincing evidence that SFO operations have and continue to improve based on forecast guidance provided by the system.

Time of Day	Run ID	Consensus					
		Fcst	Conf	Pr17	Pr18	Pr19	Pr20
09:18	0900	19:36	Good	10%	20%	50%	70%
11:12	1100	20:01	Good	5%	10%	25%	40%
13:12	1300	20:07	Good	5%	10%	30%	40%
15:43	1500	21:21	Good	5%	5%	10%	10%
16:20	1600	21:21	Good	5%	5%	5%	5%
17:24	1700	21:27	Good	N/A	5%	5%	5%
18:43	1800	20:33	Good	N/A	N/A	5%	40%

Figure 6. Consensus forecasts and probability tables for September 14, 2005 (from the SFO Marine Stratus Forecast System display interface).

ATCSCC Advisory

ATCSCC ADVZY 031 SFO/ZOA 09/14/2005 CDM GROUND DELAY PROGRAM

```
MESSAGE: AIRPORT: SFO
         DELAY ASSIGNMENT MODE: DAS
         ADL TIME: 1214Z
         ARRIVALS ESTIMATED FOR: 14/1600Z - 14/2059Z
         PROGRAM RATE: 30
         FLIGHTS INCLUDED: ALL CONTIGUOUS US DEPARTURES
         SCOPE: 1400
         ADDITIONAL FACILITIES INCLUDED:
         CANADIAN AIRPORTS INCLUDED: CYEG CYYC
         DELAY ASSIGNMENT TABLE APPLIES TO: ZOA
         MAXIMUM DELAY: 101
         AVERAGE DELAY: 55.8
         REASON: WEATHER, LOW CIGS
         REMARKS:


EFFECTIVE TIME: 141217 - 142159
    SIGNATURE: 05/09/14 12:18
```

Figure 7. GDP issued for SFO on September 14, 2005. Note that the plan was issued for CONUS as well as the international airports in Edmonton and Calgary Canada. Also note the reduced acceptance rate of 30 aircraft per hour for the duration of the program.

Time of Day	Run ID	Consensus					
		Fcst	Conf	Pr17	Pr18	Pr19	Pr20
N/A	0900	N/A	N/A	N/A	N/A	N/A	N/A
11:36	1100	17:46	LOW	30%	70%	85%	95%
13:15	1300	17:18	Good	40%	80%	95%	95%
15:48	1500	17:07	Good	50%	90%	95%	95%
16:21	1600	17:47	Good	15%	70%	90%	95%
17:21	1700	17:58	Good	N/A	75%	90%	95%
N/A	1800	N/A	N/A	N/A	N/A	N/A	N/A

Figure 8. Consensus forecasts and probability tables for July 29, 2005 (from the SFO Marine Stratus Forecast System display interface).

ATCSCC Advisory

ATCSCC ADVZY 031 SFO/ZOA 07/29/2005 CDM GROUND DELAY PROGRAM

MESSAGE:
```
AIRPORT: SFO
DELAY ASSIGNMENT MODE: DAS
ADL TIME: 1322Z
ARRIVALS ESTIMATED FOR: 29/1600Z - 29/1859Z
PROGRAM RATE: 32/40/45
FLIGHTS INCLUDED: ALL CONTIGUOUS US DEPARTURES
SCOPE: 1000
CANADIAN AIRPORTS INCLUDED: NONE
DELAY ASSIGNMENT TABLE APPLIES TO: ZOA
MAXIMUM DELAY: 75
AVERAGE DELAY: 30.3
REASON: WEATHER, LOW CIGS
REMARKS:
```

EFFECTIVE TIME: 291326 - 291959
SIGNATURE: 05/07/29 13:26

Figure 9. GDP issued for SFO on July 29, 2005. Note the increasing acceptance rate from 32 to 40 to 45 aircraft per hour in the final few hours of the program.

7. ACKNOWLEDGEMENTS

8. REFERENCES

Clark, D.A. and F.W. Wilson, 1996: The Marine Stratus Initiative at San Francisco International Airport, Massachusetts Institute of Technology, Lincoln Laboratory, Project Report No. ATC-252, Lexington, MA 41pp.

Clark, D.A., C.F. Ivaldi, F.M. Robasky, K. MacKenzie, R.G. Hallowell, F.W. Wilson, and D.M. Sinton, 2005: SFO Marine Stratus Forecast System Documentation, Massachusetts Institute of Technology, Lincoln Laboratory, Project Report No. ATC-319, Lexington, MA (in draft).