J1.2 IMPLEMENTATION OF ENHANCED SHORT TERM AND AVIATION GRIDS AT THE NWS ATLANTA FORECAST OFFICE

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1. INTRODUCTION

As the National Weather Service (NWS) approaches full implementation of Digital Aviation Services (DAS), select Weather Forecast Offices (WFOs) are making the transition ahead of schedule in order to determine which methods for providing DAS will be most appropriate for the entire NWS. All of the NWS's Eastern Region (ER) offices have transitioned to Enhanced Short Term (EST) grids, which consists of three-hourly updates to the short-term forecast (generally 0-48 hours). Many NWS Central Region WFOs have also transitioned to an EST paradigm. Additionally, several WFOs, mainly in the NWS ER, have already transitioned DAS, which consist of additional forecast parameters specific to aviation (Waldstreicher et al. 2012, Sims et al. 2011). As part of the transition to DAS, WFO Boston/Taunton, MA, has developed a Terminal Aerodrome Forecast (TAF) formatter within the Graphical Forecast Editor (GFE).

WFO Peachtree City, GA (FFC), responsible for aviation forecasts for the Hartsfield-Jackson Atlanta International Airport (ATL), the world's busiest airport, is part of the NWS's aviation "Golden Triangle," also consisting of WFOs Chicago and New York. Because of ATL's unique needs associated with additional wind direction and sky cover requirements (see Section 1c), WFO FFC, in conjunction with the Center Weather Service Unit (CWSU) in Hampton, Georgia (ZTL), has taken a slow, deliberate, tiered approach to this transition to EST and DAS (locally named Über Grids), consisting of four major steps: winds, weather (specifically convection), visibility, and ceiling. As part of this test, an Über Grids (ÜG) team was formed in 2010, with half of the members assigned to the Development Team (ÜGDT) and the other half assigned to the Evaluation Team (ÜGET). It was the ÜGDT's responsibility to develop software, practices, and procedures for the transition, and the ÜGET's responsibility to test each phase of the transition before the entire staff was transitioned.

a. *Background and motivation*

In an era of ever-increasing Decision Support Service (DSS) activities, the traditional method of preparing forecasts in 12-hour increments is not suitable for our customers' needs. The GFE software used in WFOs has the ability to subdivide forecast elements into hour-long increments, but traditionally this capability has only been used for temperature, dewpoint temperature, wind, and elements derived from these three (such as apparent temperature, wind gust, etc.). Probability of precipitation (PoP) and weather (Wx) grids are handled differently at each office, but only recently have WFOs begun exploring the idea of producing these grids in hourly increments.

The ÜG concept was first proposed after inconsistencies between the WFO public and aviation forecasts were noticed. For example, the public forecast may have included "a chance of afternoon showers and thunderstorms," whereas the associated TAF may have had no mention of thunder. These inconsistencies were not limited to convective weather; differences in wind speeds and direction (including timing of wind shifts) and cloud cover were noticed as well. These inconsistences were a disservice to our aviation partners and customers, as plans made around the TAF might not necessarily be the same plans if made from the public forecast.

b. *WFO Peachtree City Operations*

WFO FFC employs a staff of 12 shift-working meteorologists, with additional management and support staff typical of most offices. In 2010, because of the strong partnership with ZTL, the Federal Aviation Administration (FAA), and local airlines, a new "Aviation Services Meteorologist"

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position was created to facilitate communication between the members of the aviation community.

Historically, because of the emphasis on the aviation program, WFO FFC split up office operations into “public” and “aviation” components of the forecast. Many other offices split the forecast up into “short term” (ST) and “long term” (LT) components, with the ST generally ranging in the first 24 to 48 hours of the forecast. WFO FFC’s operations plan did allow for extra attention to aviation concerns, but because of the splitting of responsibilities within the same time periods, this enabled the aforementioned inconsistencies in the forecasts to go unnoticed. As part of the transition to ÜG, the teams understood that the office paradigm would likely have to shift from a public/aviation one to a ST/LT one, specifically adopting a “constant update” mentality for the ST and especially near term (NT) grids to ensure that the grids always reflect current thinking. In doing this, the NT period is generally 0-12 hours and the ST period has generally been defined as 12-36 hours, with the LT beginning thereafter. In a complicated weather scenario, the ST desk would have the option of only concentrating on the first 24 hours of the forecast, or possibly employing a team mentality in order to complete the grids.

c. ATL-specific concerns

The Hartsfield-Jackson Atlanta International Airport (ATL) is the busiest airport in the world; in 2011 alone, it served over 92 million passengers and had almost a million aircraft movements (a movement is either a takeoff or landing at an airport) (ACI 2012). ATL is also first on the list of Operational Evolution Partnership airports. The maximum airport arrival rate (AAR) is 126 aircraft per hour, and ATL routinely operates at capacity. Any weather phenomena that might impact the airport could thus have a cascading effect across the entire National Airspace. In 2009, ATL had more weather-related flight delays than any other airport in the country at over 47,000 delays (Smith and Tongue 2010), almost 10,000 more delays than the next airport on the list.

There are five parallel runways at ATL (Figure 1) which allows for the high AAR. The Air Traffic Control (ATC) tower at ATL is approximately 400 ft and was built in 2006 to allow controllers to visually see all five runways (West and Skov 2009), the farthest of which is 2 SM from the tower. This configuration has enabled ATL to reach the “world’s busiest airport” status, but also

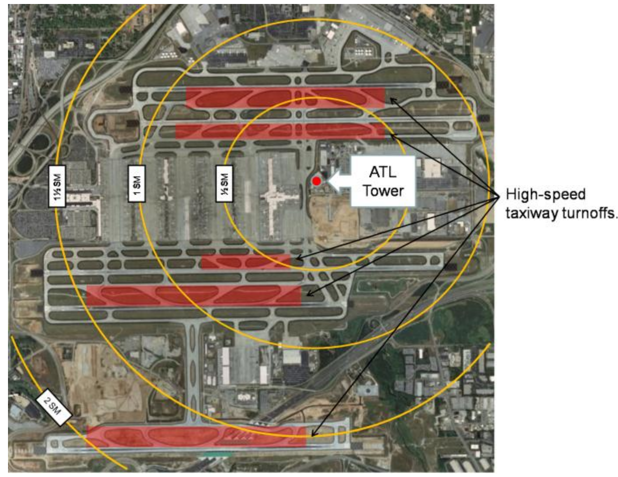

Figure 1. Aerial photo of the Hartsfield-Jackson Atlanta International Airport. The high-speed taxiway turnoffs are highlighted in red for all five east-west runways. From West and Skov (2009).

results in challenging airport operations during a variety of meteorological situations. Some examples include:

1) A due north or due south wind direction results in crosswinds. The general threshold before the AAR would be reduced at ATL for crosswinds is about 20 kt.
2) A slight tailwind component (3-6 kt) can be tolerated, but if the wind direction changes from the east to west or vice versa, the airport must be “turned around” to allow the planes to take off or land into a headwind. Outflow boundaries (related to the difficulty of convection forecasting) and mistimed frontal passages are two of the main forecast issues that result in flight delays of this nature.
3) Ceilings of 400 ft or lower result in the ATC tower being “in the clouds.” Under Federal Aviation Administration (FAA) procedures, when controllers lose visual contact with an aircraft that has just landed and is using the high-speed turnoffs (Figure 1), they must wait for radio confirmation that the aircraft has completed its landing, is off the runway, and on the taxiway before giving clearance for the next aircraft to land. This requires that airplanes be spaced further apart on final approach, dropping the AAR (West and Skov 2009).
4) During maximum AAR, airplanes on final approach line up and must only maintain visual separation between the aircraft

(e.g., as long as a pilot can see the airplane in front of him/her, the pilot is only required a minimum of 2 SM separation). However, as moisture increases below about 6000 ft above ground level (AGL), this can result in reduced visibility from either hazy conditions or actual condensation into clouds. At this point, pilots must increase the separation between aircraft during final approach to a minimum of 3 SM, which reduces the AAR.

Because of these challenges, WFO FFC provides enhanced services to ATL when completing TAFs. Unlike most TAFs which are valid for 24 hours, the ATL TAF is valid for 30, as are TAFs for many other airports that are used for international flights. Routine amendments are also created every two hours in addition to the scheduled 0000, 0600, 1200, and 1800 UTC routine TAF issuances. Instead of limiting amendments and details in the TAF to the standard flight categories (Table 1), the ATL TAF is written to account for the additional meteorological requirements listed above.

d. CWSU ZTL Gate forecasts

ZTL issues convective "Gate" forecasts for the four arrival and four departure "gates" associated with ATL. An additional goal of the overall ÜG project was to convert from the CWSU hand-creating these forecasts to one in which the forecasts come out of the WFO GFE database. This also would help with addressing consistency issues between offices and forecasts. For additional information on this project, see West et al. (2013).

Table 1. Standard flight categories (FAA 2012).

Standard Flight Categories	Ceiling (ft AGL)	Visibility (SM)
Visual Flight Rules (VFR)	>3000	>5
Marginal Visual Flight Rules (MVFR)	1000 to 3000	3 to 5
Instrument Flight Rules (IFR)	500 to <1000	1 to <3
Low Instrument Flight Rules (LIFR)	<500	<1

2. Project outline

The concept of ÜG was first proposed in the fall of 2010 with the focus of making GFE the WFO's sole production tool, to:

1) Produce meteorologically-consistent forecasts, regardless of delivery medium and customer base;
2) Improve the quality, precision, and detail of our current grid-based forecasts; and
3) Begin moving us in the direction of 4-D Wx Data Cube (as part of the FAA's NextGen initiative).

The initial outline consisted of a two-year timetable, with a year to fully develop and a second year to test and implement the concept. The goal was to fold EST and DAS into an overall paradigm shift for the WFO.

The main elements to be tested and implemented included winds, weather (specifically convection), visibility, and ceiling. With each of these elements, the ÜGDT spent time installing or developing GFE "smart tools" to assist with the creation and manipulation of the grids, followed by a three-day test during with the ÜGET members vigorously tested the tools in an operational setting.

a. Winds

Hourly Wind and WindGust grids have been part of the normal grid suite since the implementation of the GFE in WFOs over 10 years ago. The first step of the transition process was simply to move the ST (0-36 hours) hourly wind grids from the former "public" desk to the "aviation" (ST) desk, where TAFs are completed. This was the also the first step in realigning duties within office operations to a more ST-LT approach.

The ÜGET spent three days testing this concept by running a parallel ST desk; an ÜGDT member completed the official ST forecast while the ÜGET member tested the workload and developed "best practices" for completing the 0-36 hour Wind and WindGust grids on the ST desk. This test was conducted in November of 2011, and the entire staff transitioned to ST hourly winds on 1 January 2012.

b. Weather

In a similar approach to testing winds, the two teams spent three days testing the concept of completing the suite of weather-related grids on the ST desk. These grids included probability of precipitation (PoP), weather (Wx), and Sky cover, especially with the intent of being able to use the WFO's convection forecasts as input to the CWSU Gate forecasts. The test was initially conducted in January of 2012 with the hopes of transitioning the weather-related grids to the ST desk before the climatological start of convective season. Unfortunately, with little active weather with which to work during the actual test, the team realized that another test would need to be completed during convective weather.

In the meantime, the office decided put *all* the ST grids on the former "aviation" desk in order to mitigate inconsistencies in the forecast. These grids were transitioned in early May, leading to the official renaming of the two forecast desks: the former "aviation" desk became the EST desk, while the former "public" desk became the Quality Assurance and Decision Support (QuADS) desk (Tables 2-3). The ideal concept of these two desks was that the EST desk would *always* be in the grids, updating and adjusting as necessary, with the only actual product issued on that desk being the TAF and ST Area Forecast Discussion (AFD). The QuADS desk would update the LT forecast when necessary, issue all other products, and generally act as the point meteorologist for all customer service and DSS activities.

Table 2. WFO FFC Legacy Shift Duties

<u>Aviation Desk</u>	**<u>Public Desk</u>**

• TAFs (7 sites)
   ○ Aviation AFDs
• Hazardous Weather Outlook (HWO)
• Weather watch (including hydro-related products)
	• All grids (days 1-7)
	   ○ Days 4-7 on midnight shift only
	   ○ All products from grids

Delays due to staff shortages prevented the follow-up convection testing until August 2012, during which time the ÜGET spent three days testing the concept of hourly weather-related grids. It was determined that the ideal time span for hourly PoP, Wx, and Sky grids was out to 12 hours, with 3-hourly groups out to 24 hours (and 6-hourly groups thereafter through the duration of the ST). This official PoP philosophy was implemented in operations in October 2012, though some forecasters have felt comfortable enough to complete hourly PoPs through 24 and even 36 hours, depending on the complexity of the weather.

Table 3. WFO FFC 2012 Revised Shift Duties

<u>Enhanced Short-Term (EST) Desk</u>	**<u>Quality Assurance and Decision Support (QuADS) Desk</u>**

• Short term grids
   ○ Through 24-, 36-, or 48 hours, weather dictating
   ○ Updated every 2 hours
   ○ Hourly through 12 hours
   ○ 3-hourly 12-24 hours
• TAFs (7 sites)
• Aviation and Short Term AFDs
• *"Grids/Internal Forecaster"*
	• Long term grids
	   ○ Days 4-7 on midnight shift only
	• All products except TAFs from grids
	• Weather watch (including hydro-related products)
	• Decision support activities
	• *"Products/ External Forecaster"*

However, no discussion of hourly PoP forecasts can be complete without reference to the difficulty of creating an hourly PoP forecast. Hughes (1980) wrote: "…the probability for very short periods, such as an hour or so, must be quite a bit lower than even the 6 h probability, <u>on the average</u>. This means that with the same lead time it is harder to forecast the very high probabilities reliably in a 6 h period than in a 12 h period." Thus, the shorter the length of the forecast period, the lower the probabilities should be, due to the lower relative frequency. *Scientifically* and *statistically*, the PoP forecast for any given hour should be much lower than the corresponding 6- or 12-hr PoP (see Hughes (1980) equation 9). It must be emphasized, however, that when producing an hourly "PoP" forecast for either general use or decision support, these users are likely not aware of the statistical limitations of an hourly PoP. Forecasters are therefore encouraged to think of these hourly grids as precipitation *potential* for that given hour rather than PoP – indeed, even on the NWS hourly weather graph, what forecasters are used to calling "PoP" is in fact labeled "Precipitation Potential". In this manner, forecasters should focus more on PoP (or "Precipitation Potential") *trends* rather than the exact number. For example, to a user of the forecast, there is a big difference between indicating a 60 percent chance of showers and thunderstorms between 1200 and 1800 UTC, versus a forecast during the same six-hour period that begins with 20 percent and peaks at 60 percent near 1800 UTC. The former would tell a general user that the entire six-hour period might be rainy, whereas the latter provides much more specific information and might allow a user to perform outdoor activities early in the day.

c. Visibility and Ceiling

Unlike the wind and weather-related grids, visibility and ceiling grids presented a new challenge to the office, as these grids had never been a part of the WFO FFC grid suite. Three main new grids were required: Vsby (visibility), PredHgt (predominant height), and CigHgt (ceiling height). Vsby is the horizontal visibility in statute miles, and can range from 0 to 10 SM in the grids. PredHgt is the height (in hundreds of feet) of the base of the cloud layer that contributes most to sky cover. Where the Sky grids are 57.5 percent or greater (BKN or OVC), PredHgt and CigHgt are the same. Otherwise, if Sky grids are less than 57.5 percent, the GFE TAF formatter will put in the corresponding coverage (FEW or SCT) from the Sky grid in with the height value in the PredHgt grid. The forecaster interacts with and produces grid values for Vsby and PredHgt, whereas the CigHgt grid is derived from the Sky and PredHgt.

Initially, a three-day test of visibility grids was conducted in May 2012, with the ÜGET members rigorously testing many new tools and procedures in order to best capture visibility trends. However, much like with the first weather-related test, the lack of active weather (at least, such that would have significantly reduced visibility) precluded the successful outcome of the test. All of the ÜG members also recognized that since visibility and ceiling are inherently related, the best approach to testing these grids would be to test them together. As such, the final 3-day test, combining the two grids and testing the feasibility of the new grids as well as the full suite of new GFE tools and the TAF formatter, was conducted in January 2013. This test coincided with a winter weather event, including the issuance of a Winter Storm Warning for a portion of the FFC County Warning Area, so at times the test had to be suspended in lieu of ongoing operations, but for the most part the forecasters testing the new grids were able to adequately evaluate the tools and procedures available for the new grids. However, it was to some extent fortuitous that the test took place leading up to a winter weather event, as the testing forecasters as well as the operational forecasters were able to judge with some accuracy the burden of adding the new grids during a difficult forecast shift. This event underscored the point that effective communication is *necessary* during the forecast process, and the ÜG team will be able to use this as a successful example.

The ÜGET members discovered that in the first 12 hours, Local Aviation MOS Prediction (LAMP) guidance typically outperformed other guidance, especially Short Range Ensemble Forecast (SREF). However, since LAMP guidance only goes out 24 hours and the ATL TAF requires 30 hours of data, some other guidance source must be used for at least those final six hours. By the third day of testing, a recommended approach was to initialize the PredHgt and Vsby grids with a blend of MAV, MET, and LAMP guidance, though an option was built into the newly-developed tool to use a blend of the MAV, MET, LAMP, and SREF.

Feedback from the ÜGET members after the test indicated that they were somewhat surprised at how well the guidance and related tools worked for the PredHgt grids. However, Vsby grids were significantly more challenging, especially due to microclimate effects (such as proximity to water bodies that allows fog to form faster at some TAF sites, higher elevation at other TAF sites that leads to stronger winds and thus fewer restrictions to visibility, etc.). The testers found during the three-day period that guidance usually was unable to accurately predict the lowest visibility value at any of the seven TAF sites, sometimes overforecasting and sometimes underforecasting. In the end, the ÜGET members felt that the best approach would be to forecast more of a background or prevailing visibility in the grid, and handle individual sites with hand-edits into the TAF as necessary.

Following the three-day test, however, the ÜGET members expressed a desire to continue testing the impact on operational workload as a result of the new aviation grids before introducing them to the staff as a mandatory step in operations. Thus, the ÜG team as a whole decided that the months of February and March 2013 would be used to not only allow the ÜG members to become fully familiarized with the aviation grids, but allow time for one-on-one training between ÜG members and the rest of the meteorological staff. This is a continuation of the methodical, deliberate approach to the entire ÜG concept that has been taken since the project was initially proposed. With this, the hourly grids will be extended from including the first 12 hours to the first 24 hours, in order to fully support the potential change groups in the GFE TAF formatter. The goal for full implementation of the new suite of aviation grids is no later than April 2013.

d. TAF Formatter

As part of the final phase of testing, the ÜGET also tested the GFE TAF formatter, which polls all the necessary grids in order to create a TAF from GFE. Obviously, many of the same grids that create the WFO public text forecast products play some role in creating TAFs, most of which are outlined above, such as Wind, WindGust, Sky, PoP, and Wx. To some extent, hourly temperature (T), hourly dewpoint (Td), and the quantitative precipitation forecast (QPF) are important as well, especially as it comes to fog formation as well as precipitation type and intensity. With the winter weather challenge added to the ceiling and visibility portion of the test, the ÜGET members were able to see first-hand how the TAF formatter handled some of these challenges.

The formatter polls the necessary grids and outputs a TAF based on the internal configuration. For example, the formatter will add a new line if the wind direction changes by more than 30 degrees, or if the PoPs increase or decrease above specific thresholds (in hours 0-11, the thresholds are at 25 percent and 55 percent [when "Chance" and "Likely" PoPs begin]; for hours 12+, the threshold is at 55 percent). This becomes a challenge because the TAF will add lines as necessary, but the maximum TAF length is five lines (six if a TEMPO group is used; see below for more on TEMPO groups) (Sims 2012). An additional line is allowed at ATL because of the longer TAF period (30 hours). The EST forecaster will have to delete extra lines or combine lines as necessary to conform to allowable TAF length. Some specific feedback regarding the TAF formatter during the test was that the testers would have preferred hourly TAF output, rather than having the formatter decide (based on the configuration of the formatter) when to put change groups into the TAF. By having a full 24- or 30-hourly TAF, the EST forecaster could then just delete or combine lines as necessary.

The formatter can support routine issuances of TAFs (at 0000, 0600, 1200, and 1800 UTC), as well as scheduled amendments (such as the two hour amendments required at ATL). However, the 1-hr increments of the grids necessary for the TAF formatter simply do not always have the temporal frequency to keep up with fast-changing weather situations (especially as related to convection or obscurations to visibility), and thus many unscheduled amendments will still have to be issued via legacy software. If there is a rapidly-changing situation that requires an immediate hand-edit, it is recommended that the forecaster go back to the grids once the amended TAF is out and try to reflect those changes in the grids as much as possible.

Forecasters are allowed to use TEMPO and PROB30 groups in the TAF. A TEMPO group is defined as a "temporary fluctuation in forecast meteorological conditions which are expected to last less than one hour in each instance, and, in the aggregate, to cover less than half of the indicated period." A TEMPO group may be a maximum of four hours long and should start within the first six hours of the TAF. A PROB30 group is defined as the "probability of occurrence of a thunderstorm or precipitation event, with associated weather elements as necessary (wind, visibility, and/or sky condition) whose occurrences are directly related to, and simultaneous with, the thunderstorm or precipitation event." A PROB30 group can be a maximum of six hours long and can only be included *past* the first nine hours of the TAF. (Sims 2012) However, neither of these groups is supported by the TAF formatter, and any TEMPO or PROB30 groups must be hand-edited as necessary. Similarly, as discussed above, when FEW or SCT coverage clouds below 6000 ft are forecast to impact operations at ATL, the EST forecaster must hand-type these groups into the ATL TAF since the TAF formatter as configured at WFO FFC only supports one group for cloud cover, as forecast in the PredHgt grids.

With the exception of the challenging Vsby grids as discussed above, the ÜGET members were pleased with the results from the TAF formatter. Indeed, because of the complicated weather situation during the three-day test, the actual EST forecasters during the test came to rely on output from the ÜGET member's TAFs from GFE as a first guess to the official TAFs (in all but one case the EST forecaster was another member of the overall ÜG team). By the final day of testing, when the winter weather event was in the first period of the forecast, the ÜGET member actually issued the TAFs, allowing the EST forecaster to concentrate on the challenge of winter weather grids.

3. Discussion

As mentioned previously, implementing the overall ÜG concept has been a slow, methodical process in order to obtain full buy-in from the operational staff, and the ÜG team hopes to make the final steps of the transition no later than April 2013. While the ÜG team could easily have simply “flipped a switch” on the new concepts at any time, the team felt that approach would have caused too much confusion and stress. Ideally the team would have preferred to complete the transition by the beginning of fiscal year 2013, but complications and unforeseen challenges such as staff shortages delayed some of the intermediate steps. However, by working with and adjusting to forecasters’ operational stress levels rather than moving along at the initially proposed pace, the ÜG team feels that in the end, the staff at WFO FFC will be better prepared to take the final few steps.

Initially, as WFO FFC implements the new grids and staff members get used to using the new tools, there is expected to be at least a brief increase in workload as a result of the necessary “spin-up” time and the steep learning curve associated with the unfamiliar grids and tools. However, Waldstreicher et al. (2012) indicated as part of the ER test that once forecasters became accustomed to the new paradigm, feedback from the ER offices has been that the overall TAFs have improved in quality, and forecasters do not want to go back to hand-writing TAFs. There are still some technological challenges to overcome, especially as in relation to ingesting observed ceiling and visibility grids into GFE, but Waldstreicher et al. (2012) have indicated that the benefits have far outweighed the drawbacks, and the ÜG team expects similar results at WFO FFC.

Though WFO FFC has not completed the implementation of DAS, the transition to the EST concept has already resulted in improved services to our customers and partners. Specifically, the office has received positive feedback on the increase in temporal detail and improvement in accuracy from both area Emergency Managers and partners with the United States Forest Service. In one example from 2 February 2013, fire and police departments in West Point, Georgia, responded to a large fire at a local vehicle manufacturing plant. The police spokeswoman indicated over the phone that the detail of the forecast on the meteogram accessed via the point and click webpage allowed them to respond to the fire with a much higher level of personnel safety in mind than they had originally considered possible; she also highly praised the accuracy of the forecast. Local FAA partners have also noticed a significantly improved trend with respect to TAF/grid consistency. These examples of positive feedback are similar to what has been received in the ER offices that have implemented the EST paradigm and DAS (Waldstreicher et al. 2012, Sims et al. 2011). In the end, a “good” forecast is not necessarily defined by verification scores, but rather by usefulness to the customer, and the ÜG paradigm was designed with our customers and partners specifically in mind, with DSS at the forefront of the concept.

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