UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL ENVIRONMENTAL SATELLITE, DATA AND INFORMATION SERVICE

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MEMORANDUM FOR: Sounder Project Leads
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SUBJECT: **MW/IR Disaggregation:** ***Collocation (or not) of infrared and microwave sounders on Same platform***

Scope: This memo provides background and recommendations on the need (or not) to require that microwave and infrared sensors be collocated on the same platform. This is deemed to be critical given that, historically, sensors like CrIS and ATMS have been collocated on the same platform (and co-registered). Recommendations that open the door for a departure from these previous satellite configurations, need to be well informed through extensive user consultation and expert scientific justification. This question has become very relevant to the discussions on the design and evolution of the future NOAA global observing system. Smallsats and cubesats have been studied and some of these studies have offered solutions based on single sensor payloads flown on multiple satellites in multiple orbits. This possibility is driven by the advanced maturity and lower costs of microwave and infrared sounder instruments. The driving applications scoping these recommendations include global NWP and the sounding of temperature and moisture that is used for nowcasting purposes.

Important note: *This memo was developed based on the deliberations and discussions among the core-SAT (federal employees only), following fact-finding and discussions of results and scientific facts with the general SAT.*

Executive Summary:

- ***Fact:*** NWP centers do not require microwave and infrared sensors to be collocated on the same satellite platform. Global data assimilation systems (3D or 4DVAR) exploit the data where and when measured.
- ***Fact:*** Full exploitation of Microwave sensors data does not require collocation of MW and IR sensors
- ***Fact:*** In clear sky conditions, exploitation of Infrared sensors for sounding purposes (e.g., using NUCAPS) does not require collocation of MW and IR sensors.

- ***Fact:*** In cloudy conditions, exploiting infrared data is possible through cloud clearing techniques without the use of a MW sounder, although with some degradation of performance. Note that using short-lead-time model forecasts have been shown to provide even more accurate IR sounding retrievals than the use of MW data for cloud-clearing
- ***Fact:*** If considering a fixed number of IR and MW sensors, disaggregation of these sensors on separate platforms would increase spatial and temporal coverage of global soundings which are critically important factors for improving NWP forecast skill. The proliferation of satellites needs to be balanced with the multiplication of launch costs when disaggregating microwave and infrared sensors.
- ***Fact:*** The pros of disaggregation include increased agility and flexibility in launch cadence, added coverage, improved temporal refresh and diurnal cycle sampling, enhanced benefit to NWP, reduced cost per satellite by using smallsats/cubesats technology, especially platform bus and launch costs.
- ***Fact:*** The cons of disaggregation include the likely increase in overall constellation launch costs, degradation of Infrared sounding retrievals in very active regions (convective), risk of adapting to the disaggregated configuration (departure from previous configuration), etc.
- ***Recommend:*** NOAA should consider constellations with both collocated and disaggregated instruments. NOAA applications benefit from microwave and infrared sensors whether they are collocated on the same platform or not, though the benefit may vary by application.
- ***Recommend:*** NOAA accounts for the pros and cons of disaggregation of microwave and infrared sensors (agility, resilience, benefit to NWP, risk, cost, schedule, etc.).
- ***Recommend:*** that in the case of collocated MW and IR sensors on the same platform that data collection be co-registered.

Background:

Collocation refers to having infrared and microwave sensors on the same satellite platform. Separating IR and MW sounding instruments onto separate satellites suggests important scientific questions because of the ramifications on current uses of the sounding data, primarily NWP, sounding retrievals, and nowcasting. Disaggregation could lead to more spatial and temporal global sounding coverage for the same number of sensors.

Facts, Results and Scientific Findings:

Inputs were received from major science and operation centers including NOAA, NASA/GMAO, JPSS, NRL, UKMO, and ECMWF concerning the collocation of IR and MW sensors. The inputs from other subject matter experts were also sought. Table 1 shows a summary of these inputs. These groups represent a sample of the global NWP centers, as well as satellite programs and centers in charge of processing and disseminating microwave and infrared sensor data. The comments were in response to the question as to whether there is value to keep MW and IR on the same satellite platform.

	NOAA (NESDIS)	NASA/ GMAO	JPSS	NRL	UKMO	ECMWF

Is there a requirement to have IR and MW collocated on the same platform when assimilated?	No direct advantage	Concurrent MW and IR radiances not considered	MW and IR are used completely separately for data assimilation, but together for NUCAPS. Both should be considered	Overall, there is no significant advantage for NWP to have the MW and IR collocated from a 4DVar sense, and that we could actually take advantage of the spatial/temporal differences in distributing the OBs on more than one platform	Some actual and potential advantages of having both instruments on the same platform, but they are much smaller than they used to be. I can see they might easily be offset if removing this requirement allowed us to have more observations overall.	No requirement that MW and IR must be on the same platform

Table 1. *Inputs from agency representatives. The question posed to them is whether there is value in keeping microwave and infrared sensors on the same satellite platform.*

Several SMEs polled presented the following scientific results, findings, facts:

- IR sounder and a MW sensor do not have to be on the same satellite bus or have the same view angles to perform cloud-clearing. Data collocation *a-posteriori* could be done from different platforms.
- Cloud-clearing using hyperspectral IR with a spectrally integrated, spatially co-located imager out-performs traditional cloud-clearing using MW.
- Collocated IR and MW adds information for NUCAPS users. Data assimilation (DA) could also potentially benefit from collocation (research effort on going to take advantage of collocation), but not having MW will not make the IR sounding fail. Other approaches not depending on the MW offer an alternative.
- The advantage of having the same platform and looking at the same area by both sensors is driven mainly by NWP research, not operations.
- Infrared sounding might benefit from MW/IR sounding collocation in some cases (convective regions).
- Microwave and infrared sounders will be flying on the same satellite platform (JPSS) through the 2040 time-frame. This means that there is low risk to the NOAA mission if we decide to explore disaggregation of MW and IR sensors on smallsats in the near future
- Timing of observations: Observations aren't as seamless with the environment from one sounding to the next if there is disaggregation without being in the same orbital plane.
- Temporal difference: Disaggregation does not equate to non-overlapping of MW and IR measurements. Similarly, aggregation (or colocation) does not equate with spatial co-registration.
- Collocation of MW and IR sensors on the same satellite platform guarantees temporal colocation. It requires an effort in the design of the sensor(s) to ensure spatial co-registration.

- MW and IR data can still be co-registered using ground processing techniques (footprint matching, etc) even if they are not on the same platform and there are enough overlapping orbits. We still need to understand at what point observations are not close enough in time and space to be useful.
- Flexibility should be considered: it can be foreseen that some satellites have collocated MW and IR sensors to benefit some applications, while others can be disaggregated and possibly flown in formation to benefit other applications.
- Downstream user applications are interested in good retrievals and quality soundings, which are not necessarily dependent on having observations collocated.
- Some possible benefits of disaggregation: increase in spatial coverage and temporal refresh. This in turn could lead to added benefits such as improved NWP forecast skills and the ability to derive 3D winds.
- Ideally, collocation and disaggregation should be recommended as part of a hybrid constellation of MW and IR sounders as both options have advantages to various users
- DA experts have overwhelmingly indicated that the collocation of IR and MW sensors is not required for their systems.
- Current systems (e.g., CrIS and ATMS) are collocated on the same satellite (JPSS) and the data is spatially co-registered. It is not known whether the 'actual' co-registration of the data is helping the NWP skills, even though the data are not co-registered before being used in NWP.
- It is to be determined if it is best to deploy disaggregated sensors in a close formation or if it is better to space them out to maximize temporal and spatial coverage and resolution. Answering this question might require a dedicated study.
- An additional benefit of disaggregation is the resulting flexibility to be able to fly more of one type of instrument than another.
- Note about Infrared sounders on Geo: These currently exist (on Chinese platform) or are planned on other Geostationary platforms. Most of these IR hyperspectral sounders do not have accompanying microwave sounders. Sounding disaggregation from Geostationary orbit is already being planned.

Summary of preferences by application:

	Collocation: IR and MW instruments collocated	**Same orbit, same number of IR and MW instruments as collocated, spaced ≤ 15 min**	**Disaggregation: More total observations (IR, MW, or both) than collocated (spacing TBD)**
NWP	Neutral	Not yet studied	Higher preference based on NWP centers feedback
Retrievals	Higher preference based on NUCAPS; Neutral when using only MW sounders	Slight preference due to similarity to collocated	Neutral (assuming not closely spaced)
Nowcasting	Higher preference for nowcasting using NUCAPS retrievals; Neutral when using only MW sounders	Slight preference due to ability to study time evolution of active regimes	Depends on specific arrangement of disaggregation; Some configurations of higher preference due to potential to increase spatiotemporal coverage

Table 2. Summary of SAT recommendation for NWP, retrievals, and nowcasting.

Recommendations:

Based on the facts highlighted above and, on the core-SAT discussions, we recommend the following:

- ***Recommend:*** NOAA should consider constellations with both collocated and disaggregated instruments. NOAA applications benefit from microwave and infrared sensors whether they are collocated on the same platform or not, though the benefit may vary by application.

- ***Recommend:*** NOAA needs to account for the pros and cons of disaggregation of microwave and infrared sensors. The pros of disaggregation include added agility and flexibility in launch cadence, added spatial coverage, improved temporal refresh, benefit to NWP, and reduced cost by using smallsats/cubesats technology. The cons of disaggregation include likely increased constellation launch cost, degradation of Infrared sounding retrievals in convective regions, risk posture given departure from previous configuration, etc.

- ***Recommend:*** If we design satellites with collocated MW and IR sensors (on the same platform), measurements from the two sensors should be spatially co-registered to complement the temporal colocation.