Project No. RP-11

ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
January 1, 2001 - December 31, 2001

PROJECT TITLE: Measuring the Effect of Low Water Temperature on Blanking and Grain Yield

STATUS OF PROPOSAL: Continuing

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LEVEL OF 2001 FUNDING: $24,140

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

The overall objective of this proposal is to quantify the effect of low water temperature on yield loss due to blanking and reduced plant productivity. The initial objectives of the proposal were:

1. Quantify the effect of low water temperature on the within field variability in rice yield loss. Determine what portion of this yield loss is due to blanking and what portion is due to other causes. Yield components analysis will be used to assess the precise nature of those causes.
2. Determine whether water temperature distribution and absolute water temperature can be estimated based on thermal infrared remote sensing. Develop an inexpensive means of determining those parts of a field that are subject to yield reducing stress due to low water temperature.

During the course of the project we recognized that a third fourth objectives were important and achievable, and we therefore added these to our list. These objectives are the following

3. Quantify the change in water temperature with distance from the source along a distribution canal.
4. Using the results of Objectives 1, 2, and 3, evaluate remote sensing technology as a means of estimating yield variability associated with water temperature on a regional scale.

At the field scale level, two rice fields, one near Thermalito Afterbay and another near Richvale, CA with cold water inlets from adjacent irrigation district canals were fitted with a grid pattern of "Hobo" temperature sensors (Figure 1a and b). At each grid point location water and canopy temperature were measured. As the rice grew, the canopy sensors were moved upward so that they were always near the top of the canopy. Hourly temperatures were recorded from both sensors throughout the growing season. At harvest, yield components and percent blanking were recorded in the vicinity of each sensor. Sensors were removed prior to harvesting and yield maps were created of the field. In addition, thermal infrared remote sensing was used to record thermal images of the field.

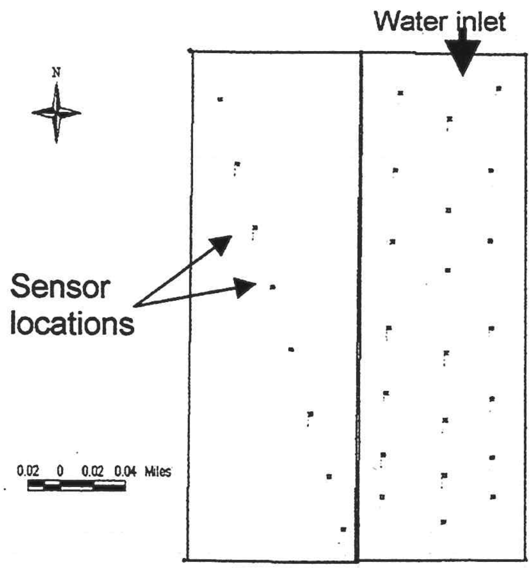


Figure 1a: Thermalito Afterbay field study

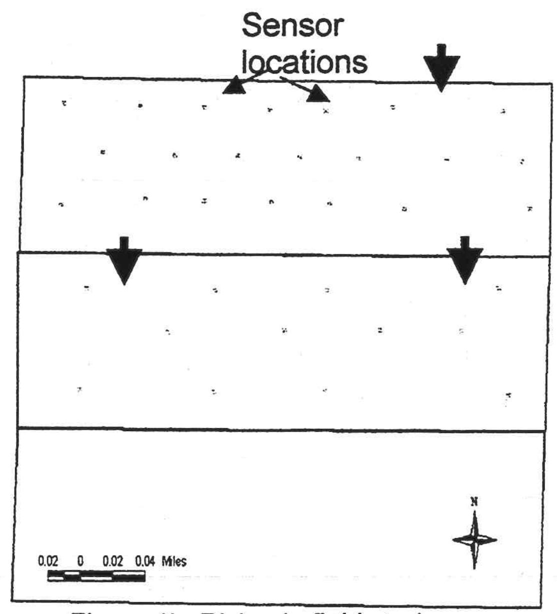


Figure 1b: Richvale field study. Sensor locations deployment

Thermal infrared images made from an airplane of the same rice check where the temperature sensor were located showed the same temperature distribution. This provides preliminary evidence that early morning temperature distribution, or at least the location of cold areas of the check, can be detected using remote sensing from an aircraft

Same kinds of sensors used at the field scale level were used to monitor water temperature at several locations along an irrigation network (Figure 2).

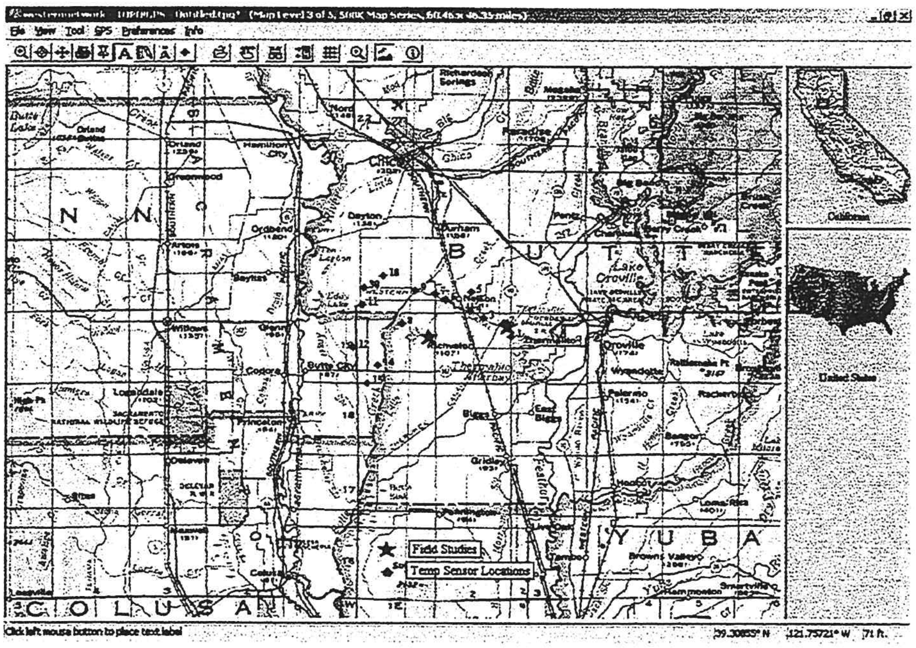


Figure 2: Dots indicate the locations of the temperature sensor along the irrigation network. Stars indicate the locations of the fields scale level studies.

SUMMARY OF 2001 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

Based on the results of the preliminary 2000 experiment, the probability of determining a significant relationship between water temperature and yield loss due to both blanking and other causes is very high. Blanking percent was related to water temperature, and total yield and yield components were also related to low temperatures at various times during the season and to degree-days.

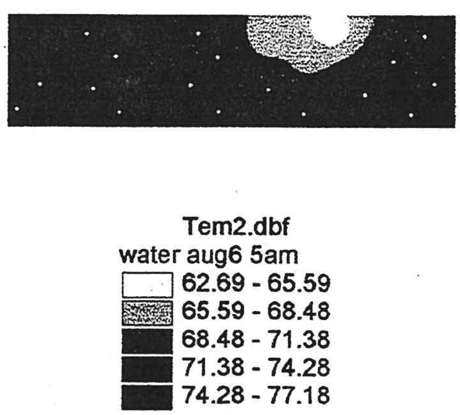


Fig. 3a. Water temperature profile at 5 am on August 6. Richvale location.

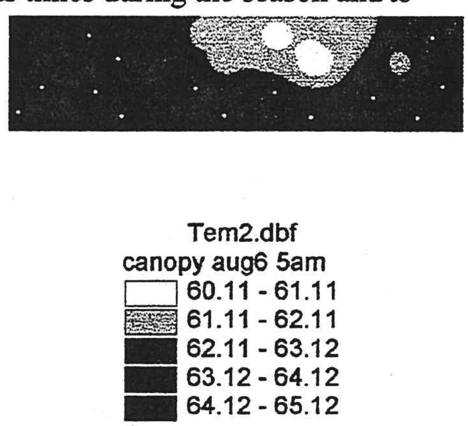


Fig. 3b. Canopy temperature profile at 5 am on August 6. Richvale location.

Fig.3 shows the water and canopy temperatures at 5am on August 6, during the period of late panicle development. At the Richvale location, it is evident that the pattern of canopy temperature at this time closely matches that of the water temperature and is somewhat lower, due to the thermal inertia of the water. Although the spatial pattern of water and canopy temperatures are similar, the absolute difference between water and canopy temperatures is much less in the colder part of the field than in the warmer part. The night-time low at the Durham weather station on this day was 56°F. This would indicate that the relatively warmer water provides sufficient thermal buffering that the distribution of early morning canopy temperature reflects that of the water temperature.

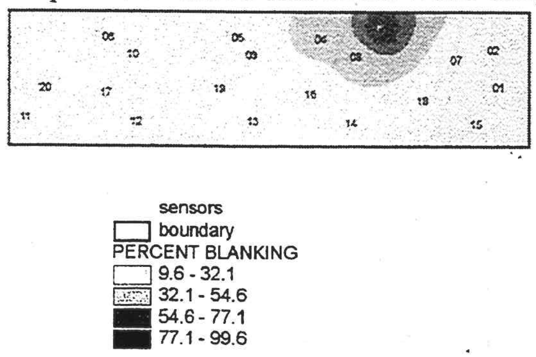


Fig. 4a. Percent blanking in the experimental check. Richvale location.

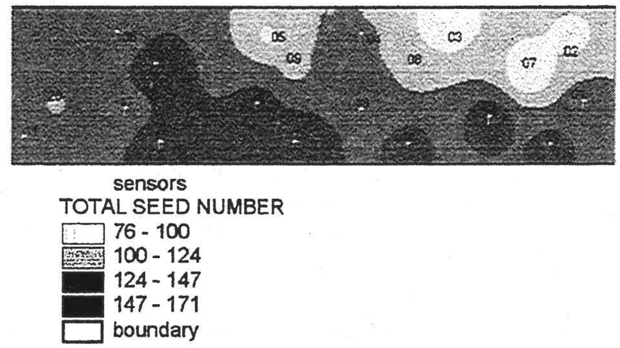


Fig. 4b. Total seed number in the experimental check. Richvale location.

Fig. 4 shows two of the yield components in the check. Both percent blanking and total seed number are significantly reduced in the cold water area. This provides a preliminary indication that cold water can significantly reduce yield due to causes other than blanking. Such effects can include poor stand establishment, reduced vigor, and delayed maturity.

The same relationship between temperature and yield was found in Afterbay location. Figures 5a and 5b show the water and canopy temperatures at 5am on July 31, 2001, during the period of late panicle development. Fig. 6a and 6b show yield and % heading. Yields ranged from a low of 1 lb/a to a high or 10693 lb/a in the experimental field. Yield trends paralleled variability in water temperature.

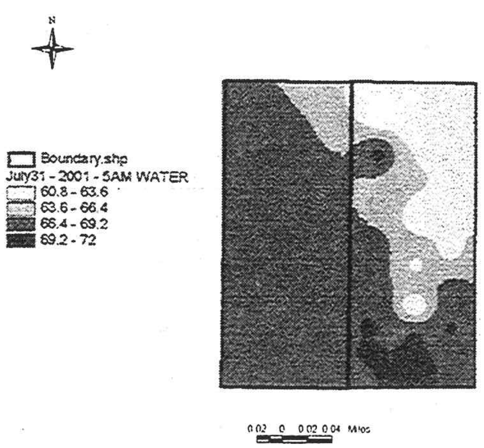


Fig. 4a. Water temperature profile at 5 am on July 31 2001. Afterbay location.

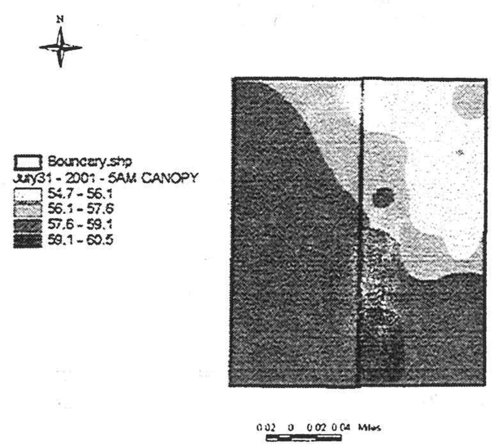


Fig. 4b. Canopy temperature profile at 5 am on July 31 2001. Afterbay location.

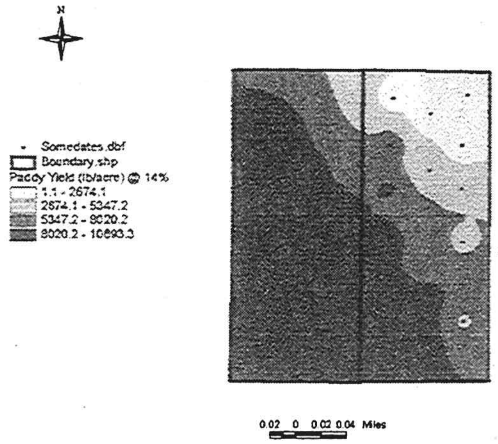


Fig. 5a. Yield 2001 (lbs/acre)

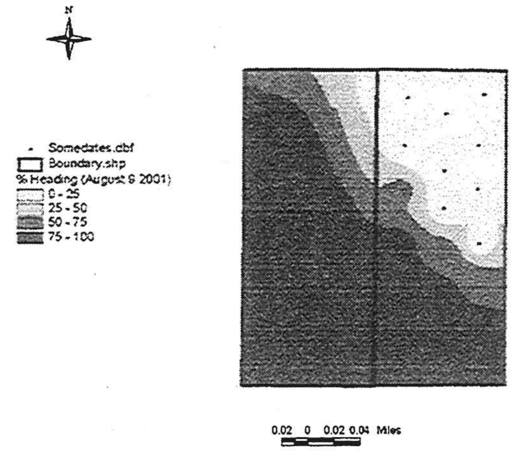


Fig. 5b. % Heading, August 9 2001.

Yield reductions were associated with delayed maturity (Fig. 5b). No differences in canopy temperatures during the thermal sensitive stage of pollen development were observed (data not shown).

Figure 6 shows a thermal image made from an airplane of the same rice check represented in Figure 4. The cooler areas of the field (dark blue) correspond to same areas in Figure 4 and 5 where differences in temperature and yield were observed. This provides preliminary evidence that temperature distribution, or at least the location of cold areas of the check, can be detected using remote sensing from an aircraft. At least one commercial company in the Sacramento Valley offers thermal remote sensing at a moderate cost per acre, and other companies have the capacity to make this service available if a market exists.

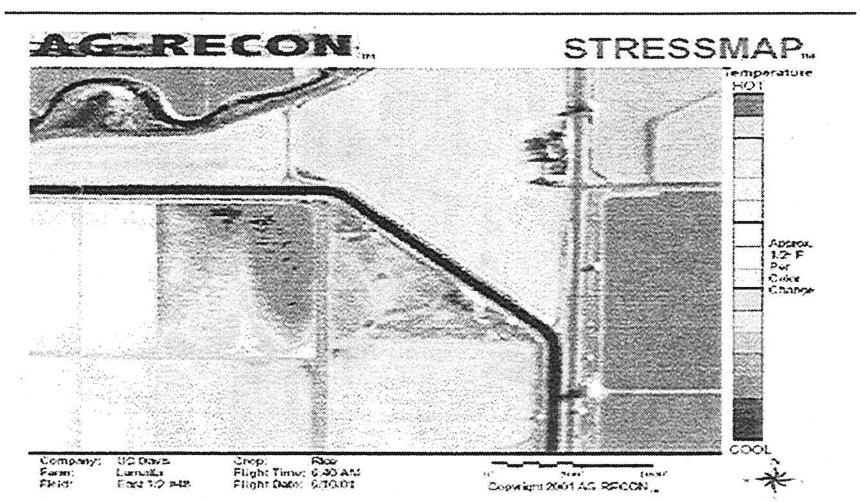
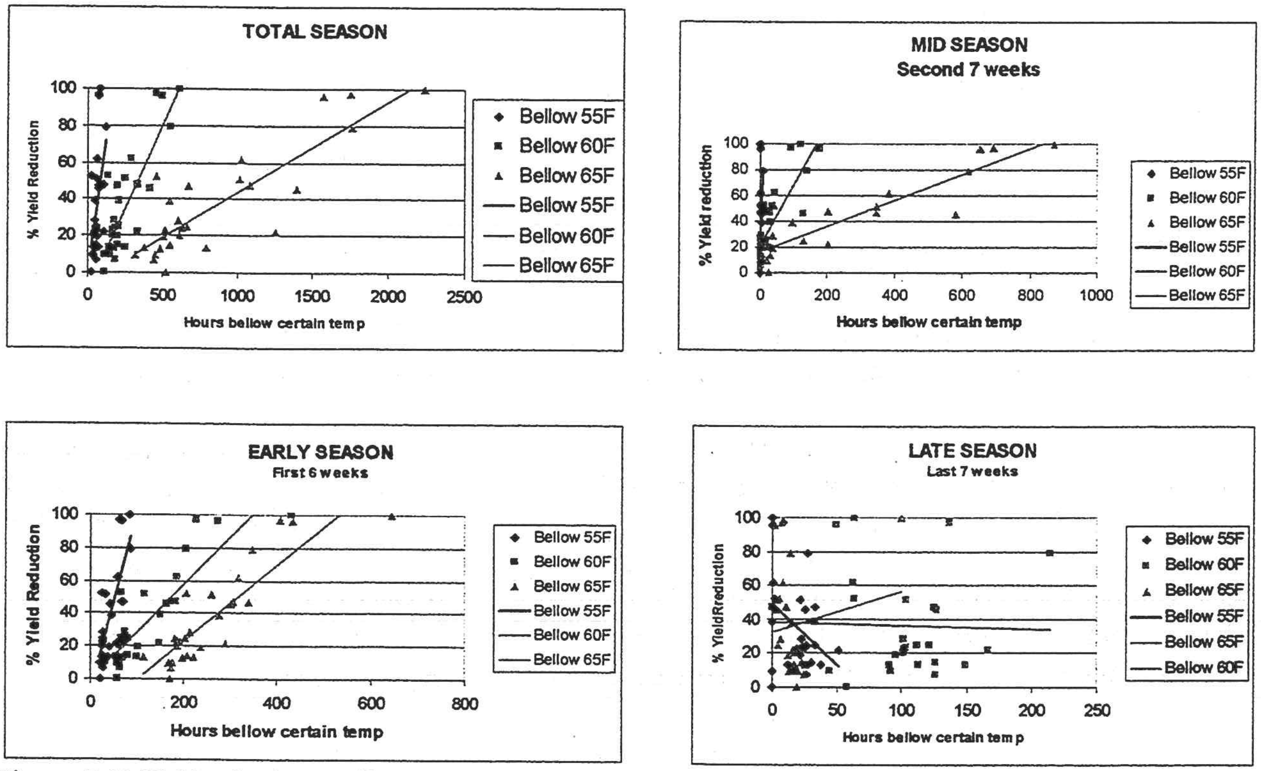


Figure 6 Temperature distribution at Thermalito Afterbay study measured using remote sensing from an aircraft. Ag-Recon, Davis, CA.

The visual comparison of water temperature and yield spatial variability indicates strong relationship between these two variables in both fields. For a further understanding of the impact of water temperature on yield a detail analysis of the effect of the moment of cold temperature and yield reduction was performed. Figures 7-10 shows the effect of water temperature, as the number of hours that the crop was under a certain temperature, at different moment of crop growth (total season, mid season early season and late season). There are very significant effects of hours below different threshold temperatures on yield reduction.



Figures 7-10 Yield reduction as affected by water temperature at different growing stages.

Slope Analysis (n=27)

**** = significant at alpha = 0.001**
*** = significant at alpha = 0.05**
n.s. = not significant

Table 1-4 shows the statistical analysis of the regression lines at each particular growing season stages (total, early, mid or late season). Apparently, what is driving the relationship between yield reduction and water temperature when all the data is taken in account is mainly the early season effect and in a smaller degree the mid season temperature. This is indirect evidence that the main effect of low temperature on yield reduction is in delaying the crop growth since there is no statistical relationship in the late season period. The slopes are statistically different among them for all the period analyzed (comparing the standard error).

Table 1: TOTAL SEASON

	Intercept	Slope	R^2	F	p-level
Bellow 55 F	-0.785	0.60	0.24	8.07	0.0088*
Bellow 60 F	-10.33	0.17	0.72	65.6	0.0000**
Bellow 65 F	-5.30	0.05	0.74	70.7	0.0000**

	Slope	Std. Error(+/-)
Bellow 55 F	0.60	0.213
Bellow 60 F	0.17	0.022
Bellow 65 F	0.05	0.006

Table 2: EARLY SEASON

	Intercept	Slope	R^2	F	p-level
Bellow 55 F	-10.77	1.12	0.64	43.8	0.0000**
Bellow 60 F	-0.76	0.29	0.75	76.4	0.0000**
Bellow 65 F	-23.71	0.23	0.77	83.3	0.0000**

	Slope	Std. Error(+/-)
Bellow 55 F	1.12	0.170
Bellow 60 F	0.29	0.033
Bellow 65 F	0.23	0.025

Table 3: MID SEASON

	Intercept	Slope	R^2	F	p-level
Bellow 55 F	23.6	8.7	0.11	3.26	0.083 n.s.
Bellow 60 F	20.2	0.48	0.72	65.8	0.0000**
Bellow 65 F	16.43	0.09	0.83	125.8	0.0000**

	Slope	Std. Error(+/-)
Bellow 55 F	8.7	4.85
Bellow 60 F	0.48	0.06
Bellow 65 F	0.09	0.01

Table 4: LATE SEASON

	Intercept	Slope	R^2	F	p-level
Bellow 55 F	49.5	-0.73	0.12	3.66	0.07 n.s.
Bellow 60 F	38.5	-0.02	0.001	0.03	0.86 n.s.
Bellow 65 F	6.08	0.08	0.26	8.77	0.006*

	Slope	Std. Error(+/-)
Bellow 55 F	-0.73	0.38
Bellow 60 F	-0.02	0.13
Bellow 65 F	0.08	0.02

PUBLICATIONS OR REPORTS:

Alvaro Roel, R.G. Mutters, James Eckert and R.E. Plant. Water temperature Impact on California Rice Production. Rice Field Day (2001)

Mutters, R.G. Eckert, J. Roel, A. and Plant, R. Measuring the Effect of Low Water Temperature on Blanking and Grain Yield on California Rice Production. RTWG 2002

Mutters, R.G. Eckert, J. Roel, A. and Plant, R. Water Temperature Impact On California Rice Production. Poster RTWG 2002.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Water temperature has increasingly become a matter of concern for California rice farmers due to the desire of regulatory agencies to improve habitat quality for fish. Based on these project preliminary results, we were able to precisely quantify the impact of water temperature in yield losses in two different fields, as well as, starting to develop the dimension of the impacts at the regional level.

The data show that these two fields present a high spatial and temporal variability in water and canopy temperature as well as very significant relationship between these behaviors and yield (Figures 4 and 5).

In summary the project allowed the quantification of the spatial and temporal variability of water and canopy temperature and their effects in final yield. Significant effect of the hours that the crop is under a threshold water temperature in yield was found (Figure 7-10). These effects are even more important during the early growing period of the rice growth (Tables 1-4), indicating that the cold temperature significantly delays crop development. This can be corroborated by the clear association between canopy and water temperature values and percent of heading observed in Figures 4a, 4b and 5b.

Previous studies have shown that cool air temperatures during the period of panicle development may lead to pollen sterility and hence to blanking and yield reduction. This project preliminary analysis indicates that even in "normal" growing season, with no problem of cool air temperature, there can be significant reduction of yield due to water rather than air temperature effects. Farmers will need to quantify and separate the effects in yield due to cool air temperature from the effects due to low water temperature to illustrate to water agencies that changes of water delivery mechanism that would substantially reduce water temperature may adversely impact crop productivity. A precise quantification of the yield loss due to temperature effects will provide the grower with the capacity to determine whether the economic gains associated with improving temperature distribution are worth the costs to make the improvement.

The good agreement between the temperature measured with our sensor (Figure 4) and the thermal aerial image (Figure 6) provide preliminary evidence that early morning temperature distribution, or at least the location of cold areas of the check, can be detected using remote sensing from an aircraft. At least one commercial company in the Sacramento Valley offers thermal remote sensing at a moderate cost per acre, and other companies have the capacity to make this service available if a market exists.