Advanced Concepts Center General Motors Corporation 2193 Anchor Court Newbury Park, California 91320

June 20, 1988

TO:

J. Albert	D. Hardwick	H. Wilson
R. Drumsta	J. Marshall	A. Brooks
M. Ferguson	J. Schinella	J. Szurpicki
D. Genord		

SUBJECT: **ELECTRIC CAR PROJECT MEETING**
Tuesday, June 28 at 8:00 a.m. at ACC

An Electric Car meeting was held at ACC on Friday, June 17 with the following people in attendance:

(Hughes) - Howard Wilson
(AeroVironment) - Alec Brooks, Robert Curtin
(ACC) - Jim Bieck, Jon Albert, Prof. John Marshall, Matt Ferguson

As a result of this meeting, it was decided by all to have another meeting on Tuesday, June 28 at 8:00 a.m. at ACC.

PURPOSE:

- o Package with outlines.
- o Tires - What has Aerovironment and ACC found out
- o Glass - Coatings/Solar reduction structure
- o Development List
  - Known concerns
  - New technologies
  - Components
- o Work with John Szurpicki (Aero/Design Staff) on design aero list (ACC) -(How & where Aero affects design)

Regards,

Jim Bieck

Jim Bieck
Manager, Exterior Design

JB/pjl
ElecCar.ACC

MEMORANDUM

TO	Howard Wilson
FROM	Alec Brooks, Paul MacCready
DATE	June 27, 1988
SUBJECT	Electric Vehicle Design Approach
COPIES TO	Peter Lissaman

We believe that the design/styling aspects of the electric vehicle project, as presently organized within the GM/Hughes/AV framework, are heading in the wrong direction. We are concerned that if these aspects are not steered onto a new path, the overall vehicle design will be compromised, and we will be unlikely to meet our performance goals.

The goal of our present program is to design, build, and demonstrate the best possible electric vehicle that could be produced in the not-too-distant future. Two of the major drawbacks of previous electric cars have been low driving range and slow acceleration. The current design goals of 120 miles range and 0-60 mph in 8 seconds are better by a factor of two over previous electric vehicles. These goals are very ambitious, and will require a great deal of attention to minimizing the weight and energy consumption of the vehicle.

In addition to the performance goals, it was also desired that car should be designed with production intent, and to account for all of the limitations imposed thereby. This would lend an air of credibility to the demonstration car. Finally, it was decided that the car should be "styled" to the degree possible considering the constraints imposed in order to meet the performance goals. It was for this reason that we approached the Design Staff and the Advanced Concepts Center (ACC). While we have had an enthusiastic response from ACC, we have had a growing feeling that their mission as a "California Design Studio" is fundamentally at odds with the design approach needed at this stage for the electric car.

In order to achieve, or even come close to meeting, our demonstration goal, we must let vehicle design and styling be determined primarily by the functional realites. We expect that the vehicle design that emerges from this approach will be quite attractive to many, but not all, people. We anticipate that a vehicle achieving the functional goals is likely to have true

and lasting beauty, both in its visual appearance and in its simple, elegant, and integrated overall design. Although designed for a very different purpose, the Sunraycer is an example of such a design philosophy. The beauty of the Sunraycer's shape and total design will still be appealing 100 years from now. Elegant engineering design is timeless.

As you know, during the period from June 20 to July 7, AV is undertaking a design effort separate from the work proceeding at ACC. The emphasis of the AV effort has been to design the vehicle focused primarily on the functional requirements, with only minimal consideration of styling. We are very pleased with the results of this effort so far, and invite you to see the ongoing work at our Simi Valley facility on Friday, July 8.

In order to ensure the continued success of the demonstration vehicle project, we recommend that the styling efforts be brought together with the engineering work under one roof, at AeroVironment. The help of the Design Staff and ACC would of course still be needed, but vehicle styling decisions that impact performance should rest with the engineering team. Although we are sure that we will not come up with a 'ugly' car, perhaps it would be appropriate for final "buy-off" of the vehicle concept and appearance to be made by a committee of three; one each from AV, Hughes, and GM (representative of technical staffs or a car group).

MEMORANDUM

TO	Electric Car Project
FROM	Alec Brooks
DATE	June 27, 1988
SUBJECT	Tire sizing
COPIES TO	

It has come to my attention that there has been direction dictated by styling considerations to increase the baseline wheel size. We need to very carefully consider all of the impacts that such a move would have on the ability of the vehicle to meet its primary objective: to demonstrate the best electric vehicle possible with current technology. While larger-diameter tires and wheels have slightly lower overall rolling resistance, many other vehicle design parameters are adversely affected. After careful scrutiny of the various factors, I believe we will find that the 17" size is excessively large for a small 2000-lb electric vehicle. Some of the repercussions of going to the larger wheel size include:

bigger tires	higher tire weight increases overall package size, upping aero drag
bigger wheel diameter	higher structural loads, more material and weight in wheels
increased gearbox ratio	higher weight and lower efficiency
increased torque on half-shafts	higher weight
need more braking torque	heavier brakes, makes non-power brakes more diffcult
higher torque reaction at motor mounts	increased structure weight
increased unsprung weight	degrades handling

Advanced Concepts Center General Motors Corporation 2193 Anchor Court Newbury Park, California 91320

June 28, 1988

TO:

J. Albert - ACC	A. Brooks - AeroVironmet
R. Drumsta - "	R. Curtin - "
M. Ferguson - "	R. Martin - "
J. Szurpicki - Des.Stf	R. Morgan - "
	B. Parks - "

SUBJECT: **ELECTRIC CAR PROJECT MEETING - SUMMARY**
Tuesday, June 28, 1988 at ACC

Following agreed to for next meeting which will take place at ACC on Monday, July 11th at 8:00 a.m. Bill Egan from Goodyear will join this meeting at 10:00 a.m.

- ACC to provide sketch for project approval by July 19th.
- Rick Drumsta will be the Project Coordinator for ACC
- Put together open-minded pros & cons list of the two packages plus advantages and disadvantages of front drive vs. rear dirve.
  - Both AeroVironment and ACC to put together dual lists
- Components List
  - Wheels (Rick Drumsta)
  - Condenser & HVAC sizing information (Bill Parks/ (Don Edburg)
  - Glass (Cy Rapezzi/Rick Drumsta)
  - Seats (Charles Buehner/Ray Morgan)
  - Small car weight data (Bill Parks)
- Continued involvement of the designers with John Szurpicki and the aerodynamic criteria.

Jim Bieck
Manager, Exterior Design

cc: J. Schinella, H. Wilson

DATE: July 12, 1988

TO:

J. Bieck	M. Ferguson
A. Brooks	R. Morgan
C. Buehner	B. Parks
R. Curtin	H. Wilson

SUBJECT: ELECTRIC CAR PROJECT MEETING - SUMMARY
JULY 11, 1988 AT ACC

Following agreed to for next meeting which will take place at ACC on Monday, July 18th at 8:00 am. Items to be supplied are for presentation to GM Corporate Management on July 28th.

- Photo of new mesh seat proposal 8 1/2" x 11" - ACC's responsibility.
- Sketch of concept of vehicle - ACC's responsibility.
- Mainstream package. 3 views (report size) - ACC's responsibility.
- Input for list of engineering support needed from other GM staffs and interface procedure.
- Help from ACC of approximate design time required on program for a complete program timing schedule to be put together by H. Wilson.

NOTE: The above items can be supplied to H. Wilson in it's final form on Tuesday, July 19th.

The following was covered in the meeting:

- C. Buehner covered seat proposal using a new lightweight mesh. ACC agreed to have a 3D concept model of seat in approximately 2 1/2 to 3 weeks. Concept drawings were approved.
- Aerovironment presented a Pros and Cons list to the two proposed packages. ACC also had a similar list. It was agreed upon that we have a mainstream package to work on and an alternate package as secondary.

  The mainstream package agreed upon as follows:

Layout

1. Front wheel drive
2. Central battery tunnel 9.25" wide, 15.25" high, 84" long

Continued . . .

Battery Systems

1. Concorde recombinant lead acid 900 lb., 27 w-h/kg
2. Delco Remy recombinant lead acid 900 lb., 31 w-h/kg
3. ENSCI bipolar recombinant lead acid 900 lb., 45 w-h/gk
4. Hughes sodium sulphur, 550 lb., 52 w-h/kg
5. Hughes bipolar sodium sulphur, 460 lb., 284 w-h/kg

Tires

1. Goodyear Custom High Pressure Radials 165/65 R14, 65 PSI

Wheels

1. Forged or spun aluminum 14" x 3 1/2"

- PPG (Frank Lovett) will be here for a meeting August 18th to discuss glass coatings, glass forming criteria and other new glass technologies. Along with paints for bodies that would reduce the heat loads.

- Alcoa (Dave Bennett) will be here for a meeting August 18th to discuss forged wheel design, alum structural body panels, and forged alum suspension systems.

- Wheels and aero wheel covers were discussed.

  1. Approximate weight figures were as follows for alum wheels:

Forged Aluminum (Alcoa)	15" x 3.5" =	8.5 lb.
	16" x 3.5" =	9.5 lb.
	17" x 3.5" =	10.5 lb.
3 Piece Aluminum (BBS)	15" x 3.5" =	9.5 lb.
	16" x 3.5" =	11.0 lb.
	17" x 3.5" =	12.0 lb.

Continued . . .

2. An aero wheel cover was proposed using a soft outer rim on the wheel cover to extend the diameter appearance of the wheel and to improve the aero effect.

- Two lightweight bumper systems were discussed.

1. G.E. lightweight bumper systems
   Lemod fascia with Xenoy blow molded bumper beam (solid mounted)

   - Advantages

     1. Lightweight (approx. 15 lb for a simple bumper)
     2. Fascia can be directly attached to front end sheet metal.
     3. Blow molded beam has minimal tooling cost
     4. Two piece bumper system

   - Disadvantages

     1. Less design flexibility in bumper profile section
     2. Lamps cannot be mounted in beam area
     3. Cannot flow air through beam area
     4. Not a completely proven system

2. Guide Flex Bumper System

   Bumper fascia - aluminum bumper beam - guide flex E/A material

   - Advantages

     1. Lightweight (no figures)
     2. Fascia can be directly attached to front end sheet metal
     3. Greatest design flexibility
     4. Can mount lamps in beam area
     5. Can have holes in beam area for air flow

   - Disadvantages

     1. Slightly heavier than G.E. system
     2. Three piece bumper system

Regards,

Rick Drumsta

Rick Drumsta
Chief Engineer - ACC

RD/dh
cc: J. Schinella

DATE: August 9, 1988

SUBJECT: Electric Car Meeting

PARTICIPANTS: John Adams ACC
Pete Bond-Nelson ACC
Scott Dolan ACC
Gary Eaker DS
Matt Ferguson ACC
Dave Millard ACC
John Szurpicki DS
Howard Wilson Hughes

- The following comments came mainly from Vehicle Aero for improved airflow and C.D.
- Front skirts - it was decided to tunnel test with and without skirts for comparison.
- Coke bottle in door and rear quarter panels to be filled for tunnel tests by Dynocing.
- A dip in center of roof was suggested to cut down frontal area.
- Wheel house tubs to be made deeper for possible track reduction. Matt Ferguson to produce layout for John Szurpicki to get tubs produced in Detroit for tunnel model.
- Flow test must be made to establish heat exchange inlet and outlet requirements.
- Inclusion of any floor bulges for motors, etc., possible rise in battery pack in rear of vehicle to help underbody C.D.
- Experiments with ramp angles and overhang to establish best combinations for C.D.. This to be done in conjunction with reducing front wrap which will bring the front lower. Hard and soft edge experiments also, to establish airflow direction under vehicle.
- Sharpening edges in front of wheel openings will help airflow around front wheels - tests to include wheel skirts and without.
- Reduce gap between rear wheels and body skin.
- Kick on rear edge of roof to be removed with steeper angle on backlite. Taper on roof to be tried in plan and side views for best combination. Foam extension sections to be made for best backlite test results in tunnel.

Continued . . .

- Harder edges were recommended at rear end roof to backlite and below backlite for better air departure.

Other items discussed were time scales for armature, modeling and tunnel testing.

- Martin Young will design an armature in Detroit. It was estimated that the armature would be completed in Detroit first or second week in September. As the Cal Tech tunnel was not greatly in demand, testing could commence as soon as model was complete.

- Glass or plastic sources would be ACC's responsibility.

- Rear view mirrors - Howard Wilson to investigate mini camera unit instead of external mirrors.

- Heat exchanger performance spec and dimensions to be determined by Howard Wilson in conjunction with latest technology on heat pumps for HVAC.

- Possibility of using a solar cell just for driving a cooling fan coupled to a thermistor for cooling vehicle when parked.

- Howard Wilson mentioned a facility in Detroit Tech Center to make stamping tools from epoxy. This could help speed up prototype panels.

Dave Millard

FILE: MILLARD.TXT
DATE: 08/10/88

August 17, 1988

John,

I thought you would like to see the enclosed article, especially the sidebar on the first page.

I am sorry if there was a misunderstanding on the tires - I guess I mistakely had the impression that we had settled on 165/65 R14 based on Rick Drumsta's memo of July 12. I agree that a detailed schedule is needed very soon, and since Howard won't be back for another two weeks, I'll start work on it right away. I'll be contacting Jim Bieck and others for ACC inputs on scheduling of certain items.

I read a good interview with you today in Car and Driver!

Sept 6, 1988

Jim,

I ran across this report on a new kind of headlight that might be good for the electric car. The feature that looks especially attractive is that the front cover can be at a shallow angle, and is simply a flat, clear piece of glass or plastic. Jerry Williams told me that typical headlight lenses (with complex optical shaping) are among the most expensive parts to make for concept vehicles.

Alec

MEMORANDUM

TO	Jim Bieck
FROM	Alec Brooks
DATE	Sept 8, 1988
SUBJECT	Santana controls, instruments, charge connections
COPIES TO	Howard Wilson

Jim,

Here is a list of controls and instruments that will be needed. It is likely that a few others will be added later. Also included is information on the recharge connection. The filter and contactor box for the recharging system is a new component for under the hood.

Also, Alan Cocconi has been doing more detailed design of the inverter package, including wire routing and air flow paths. A copy of the newest design is attached.

Santana EV Controls and Instruments

ANB 9-8-88

Controls

Steering Wheel
Accelerator pedal
Brake pedal
parking brake
drive mode select switch: fwd, rev, neutral
key switch, off, accessory, on
cruise control switches
headlight/parking light switch
headlight high/low beam switch
wiper switch
rear window defr. switch
windshield defr. switch
HVAC controls

Instruments

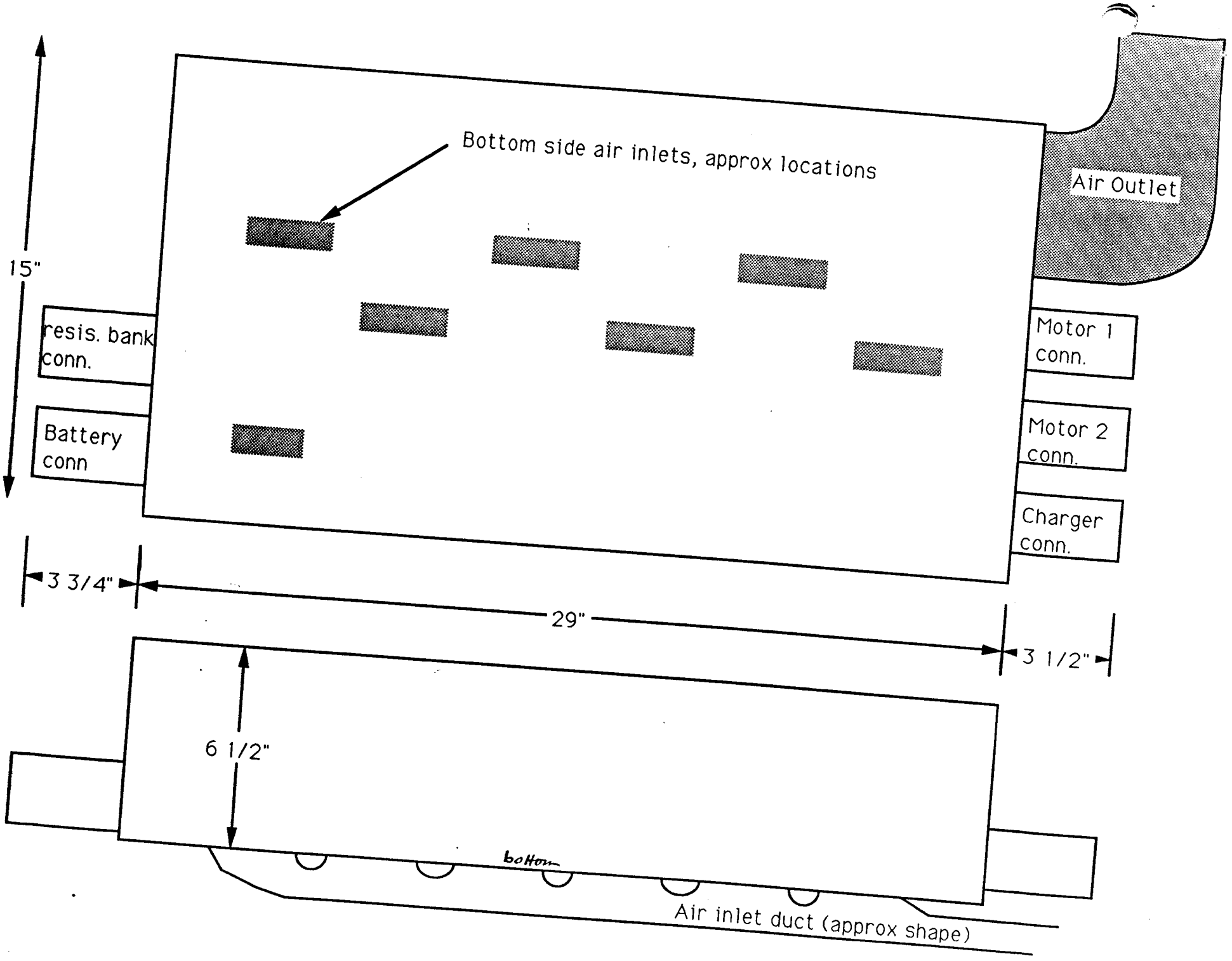
Speedometer	analog or digital?	0 to 80 mph
motor temp	analog bar graph	0 to 200 deg C
battery charge state	digital	0 to 100% or?
battery current	analog bar graph	-400 to +400 Amps
battery voltage	analog bar graph	200 to 400 Volts
battery temp	analog bar graph	0 to 70 deg C

Warning lights

motor overtemp
electronics overtemp
electronics fault
low battery

Recharge System Notes

The recharge system will need a small door (like gas tank filler door) on the car body near the front of the car. There will be a 1/2 cu ft electronics box containing a filter and contactors right behind the door. There will be two plug connections possible: 110 V 2 phase, and 208 or 230V 2 phase. Provisions for both types will have to fit behind the door. If space permits, we may want to consider a power cord on a retracting reel (like a vacuum cleaner) for easy charge connection (This would be for the 110 V connection only).


Bottom side air inlets, approx locations
Air Outlet
15"
resis. bank conn.
Battery conn
Motor 1 conn.
Motor 2 conn.
Charger conn.
3 3/4"
29"
3 1/2"
6 1/2"
bottom
Air inlet duct (approx shape)

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Advanced Concepts Center General Motors Corporation 2193 Anchor Court Newbury Park, California 91320

DATE: September 14, 1988

TO: Alec Brooks - AeroVironment, Inc.

SUBJECT: Electric Car - Criteria for ACC

Howard Wilson asked me to send the accompanying list to you. These are items that we need information on to design the Electric Car at ACC. We have listed those of prime importance to get the design going; there will be more as the program progresses.

We discussed most of the items on the list with Howard Wilson when he visited ACC September 8th. During a phone conversation September 13th, he told me that these same items were being discussed while he is visiting the Detroit area.

If you wish to contact me about this list or any of the items on it, I am at ACC in Newbury Park and my phone number is (805) 499-0255.

D. MacFarlane

Don MacFarlane
Mgr. Engineering Services

DM/dh
cc: J. Adams
J. Albert
J. Bieck
R. Drumsta

ELECTRIC CAR

Criteria items required by ACC:

- Wheel envelopes
- Suspension components including wheel/brake, steering, springs, arms, etc.
- Structure components; particularly:
  - Front end
  - Rear end
  - Front body hinge pillar
- Front of dash height and related components including plenum
- Bumper systems (assume Guideflex but what is offset)
- Position on "legal" requirements to be met
- Trim heights
- Restraint system
- Steering column location and angle
- HVAC components

FILE: Car.Txt
DATE: 09/13/88

MEMORANDUM

TO	P.B.S. Lissaman, P. MacCready
FROM	Alec Brooks
DATE	October 2, 1988
SUBJECT	Electric Vehicle Project Status Report

1. Contracts

Hughes funds (project no 70007) have covered approximately through September 1. AV opened a new project number at this time. Randy Arickx (contracts person at GM AES) will date new contract with AES starting September 1. We are still awaiting the executive committee's approval for final contract. Don Atwood, who was to confer with Roger Smith for final approval, is still in the hospital with back problems. Gary Dickinson has taken the responisbility for finding out what is happening with the contract.

2. AES visit in mid September

Howard and I visited AES Sept 12 - 14 for briefings by many of the technical disciplines within AES. Their have a great deal of interest in our project, and will try their best to support it. At that time, it seemed likely that they would send two or three engineers to California for several months to support our project, although they have backed away from this idea recently. One of the things that emerged from our meetings was the necessity of having the vehicle layout and package designed by engineers rather than stylists. They recommended a meeting for this purpose be held as soon as possible. After considering the alternatives, it was determined that it made the most sense to hold the meeting at the GM AES facility in Warren.

3. AES packaging meeting September 29 through Oct 4

Attended by Howard Wilson, myself, Bill Parks, Bob Curtin, and Dave Busch. With assistance of various experts at AES, the vehicle package was defined in full scale. Included in the package are battery, motors, suspension, steering, inverters, bumpers, structure, and passengers. We evaluated the suspension and steering components of a Honda CRX, and found them to be quite suitable, with perhaps minor modifications.

4. Project Status

wind tunnel	behind schedule by at least one month due to delays in vehicle styling effort.
structure	There has been very little effort in this area in the last month. A meeting will be held at Simi Wed Oct 5 to review the progress made at the GM packaging and layout meeting, and discuss plans for future work.
motor	Lucas Western has a PO from us for the prototype motors. We performed coast-down tests on a mockup motor to measure windage and bearing losses. Losses were only 1/5 as much as predicted by Western, so cruise point efficiency is now expected to be above 95%. A dynomometer is being assembled to test the new motor and inverter. A test motor has been borrowed from JPL to facilitate early testing of the inverter.

gearbox	Camelot engineering has completed the initial design of the gearbox and motor housing. A separate gearbox for the dynomometer will be completed later this week.
battery	A battery design review was held at AeroVironment in late August. Delco-Remy presented data showing the trades between energy and power. A design point was selected based on achieving full acceleration capability subject to the inverter current limits.
electronics	Alan Cocconi has completed the phase modules and logic control board for one inverter, and is working on the packaging. Also completed is the 100 Amp 12V auxilliary power supply.

5. Interface with Advanced Concepts Center

a) We have been working with ACC for nearly 5 months. In general, they have worked very slowly, and have not been responsive to meeting the technical requirements of the vehicle. They have been very difficult to work with, and have indicated indirectly that they don't think we at AeroVironment have enough knowlegde to design the car. For example, when we try to offer suggestions or have a technical discussion with them, the standard response is that they want to discuss the issue with the experts at GM or suppliers, rather than with us. They are not yet out of concepting stage and have not yet considered people packaging, styling considerations for open wheels, solar load, glass weight, and many other important design considerations.

b) It is my judgement that the program cannot be completed within the original time span of 15 months if we must continue to work with ACC.

6. Recommended modifications to the program:

Instead of building two identical cars in the 15 month time frame, initiate a two pronged parallel program.

- AV/AES builds an "engineering mule" vehicle with no styling input to confirm performance goals.
- ACC undertakes slower-paced program to design a second generation styled electric vehicle, using input and experience from the mule car.
- Program time scale expanded slightly - mule vehicle to be completed in 12 - 15 months. ACC vehicle construction follows completion of mule vehicle.
- The budget for the mule vehicle is less than original estimate for the first car due to faster design of the vehicle (no interaction with ACC on this one speeds us up) and use of existing components. Budget for second vehicle to be determined, but total program dollars will probably be greater than first estimate because two different vehicles will be built.
- The mule vehicle could be engineered quickly, with the help of AES. Good working relationship with AES encourages fast progress and high productivity.

With this approach, we could still meet our original goal of vehicle package and exterior design (including wind tunnel) by Christmas. Howard Wilson has planted the seeds of the mule vehicle idea with Don McFarlane at ACC, Klaus Wilkelmann, Don Runkle, and Gary Dickinson. Howard will speak to John Schinella this week. It is possible that all involved will agree with the new approach.

Advanced Concepts Center General Motors Corporation 2193 Anchor Court Newbury Park, California 91320

DATE: October 25, 1988

TO: Distribution

SUBJECT: Electric car Meeting Minutes

The minutes from the most recent meeting between AeroVironment and Advanced Concepts Center on the Electric Car program are attached. John Schinella suggested copies be sent to you in the interest of closing the communication loop.

D. Macfarlane

Don Macfarlane

DM/dh

October 19, 1988

TO: John Schinella

SUBJECT: Electric Car Meeting - AeroVironment/ACC - October 14, 1988

On October 14, AeroVironment and ACC people met at both the AeroVironment Simi Valley office and ACC to discuss the Electric Car. Those attending were:

AeroVironment	ACC
A. Brooks	J. Adams
D. Busch	R. Drumsta
W. Parks*	D. Macfarlane
W. Watson	D. Millard
H. Wilson	

* AeroVironment office portion of meeting only.

The meeting was held to review criteria and discuss making the reach car the prime vehicle for the program. The results for each of these was not completely satisfactory. Little has been done in the way of additional criteria development and there is not full support for the reach car.

CRITERIA

- **Front Suspension:** ACC asked for more definition on the front suspension. AV (AeroVironment) stated that they were staying with CRX design and hoped to lower the strut about two inches. The only dimensional data they have is shown on the general layout drawing given to ACC October 4. No further work has been done on the drawing. AV gave ACC some notes to explain the data points on the drawing and some service manual sketches of the CRX suspension.

- **Front Wheel Envelope:** Through AV it was learned that Design Staff was doing a computer development of the Electric Car front wheel envelope. Arrangements have been made to transmit the envelope to ACC. The envelope was done to the same approximate data that is on the vehicle layout drawing.

Continued . . .

- **Front Bumper:** Additional work is required by ACC and AV to get the bumper bar properly positioned, fore and aft, with respect to the surface.

- **Head Lights:** It was agreed to make sure the head lights are located and illuminate legally but not to be concerned about aiming considerations.

- **Heater/Air Conditioner:** The package size and location of the heater/air conditioner unit as it will go into the car has not been determined. AV has a Japanese room unit that comes in two major pieces. These have to be taken apart, the essential pieces removed, and then assembled for the car.

- **Plenum:** A cross-sectional area for the plenum has not been established.

- **Driver Location; Fore/Aft:** ACC and the general layout drawing disagree on the location of the driver in the fore/aft direction. The forward location shown on the general layout is favored by AV for weight distribution. The ACC position is based on an anticipated wheelhouse inner location. ACC agreed to reposition the driver, if possible, after the wheelhouse inner is established from the wheelhouse envelope.

- **Driver Location to Centerline:** As the general layout was developed, the driver was moved outboard to give additional clearance to the batteries. It put the driver's head into the roof. This location is preferred by AV as it would possibly cause a stiffer tumblehome and this would "reduce sunload". When ACC objected and cited increased frontal area and its effect on aero as one of the detriments, AV stated that sunload was more important than aero in this case. There is no agreement on the driver location with respect to centerline.

- **Door Glass:** ACC's design uses hardtop door glass in order to minimize frontal area with the desired tumblehome. AV wants to use 3mm thick sideglass for weight reduction. For this reason, they want door frames to stabilize the glass even though it would increase the frontal area. Agreement was not reached on this item.

- **Rear Bumper:** Although the general layout showed the rear bumper as though it were an add on piece, it will be integral with the rear fascia. ACC will show the bumper bar within the fascia.

Continued . . .

- **General Structure:** The load paths for the vehicle have not been established. Work is required on the structure, particularly in the front end where it appears to be interfering with the suspension.

- **Electrical Components:** ACC asked for detail drawings of the electrical components. AV pointed out that some components were shown on the general layout and drawings of others had been sent to ACC, but they would send new drawings.

Very little true resolution was reached during the criteria discussions. Dates were not established and it appears that there will not be much vehicle engineering support from AV.

REACH CAR

AV's feeling toward the reach car is negative. They expressed concerns about aero qualities, weight due to anticipated structure, and need for a design that relates to the product. In addition, they are not convinced that GM Engineering Management supports the reach car.

Howard Wilson did state that if General Motors would allow AV to build a demonstration vehicle not using an ACC shape, AV would support the ACC reach car. His plan is to have parallel programs (engineering only, shape only) with a combined program as a second stage. Their support during this would consist of advice with respect to the electric aspects of the car and critiques of ACC's package drawing. There would not be vehicle engineering support as would be expected if an organization such as AES were directly involved.

D. MacFarlane
Don MacFarlane

DM/dh
cc: J. Adams
J. Albert
J. Bieck
C. Cunningham
R. Dakins
R. Drumsta
M. Ferguson
D. Millard

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→PBSL /

PBM ✓ me

return to Alec.

DISTRIBUTION Macfarlane was a lot happier after his visit to Simi yesterday (10-27).

A. Brooks	-	AeroVironment
C. Jordan	-	Design Staff
K. Pickering	-	Design Staff
D. Runkle	-	A.E.S.
J. Williams	-	A.E.S.
H. Wilson	-	AeroVironment

MEETING MINUTES
October 27, 1988
ELECTRIC CAR

A meeting was held at the AeroVironment Simi Valley facility October 27, to discuss the Electric Car. Those attending were:

J. Adams - ACC	D. Millard - ACC
A. Brooks - AV	F. Miller - AES
D. Busch - AV	J. Williams - AES
D. Macfarlane - ACC	H. Wilson - AV

Other AV and AES people were at AeroVironment but did not participate directly in this meeting. Also, Alec Brooks and Jerry Williams visited ACC earlier in the day, in addition to being at the meeting.

The items of discussion were the general operation of the program and criteria.

PROGRAM OPERATION

Based on a meeting with G. Dickinson and Don Runkle, Howard Wilson stated that the program would be run on the parallel path plan. That is, AV would build and test a demonstration vehicle while ACC develops the shape. At a later point the two would be brought together to build the final vehicle.

AV intends to build their demonstrator along the line of a Peugeot prototype, Vista, which is reported to have a C_D of .190. The vehicle will be made of fiberglass, or similar materials, with construction and weight simulating metal construction. The interior will be "bare bones" in terms of appearance and amenities.

With this plan AV would support ACC with information developed while building the demonstration vehicle and advice on the packaging of the ACC vehicle. ACC would be expected to develop a vehicle that is most appropriate for the Electric Car concept.

Continued . . .

CRITERIA

- **General Structure** - AV has a one third scale structures model underway. In addition, the structural components, details of the suspension are being shown.

- **Front Suspension** - The CRX front suspension is still being planned on for the Electric Car. It will be used in the AV car and it appears that would work in both the base and reach cars ACC is working on.

- **Rear Suspension** - AV has not selected a rear suspension. The CRX has a member that would hang below the floor pan and increase aero drag.

- **General Arrangement** - A new general arrangement drawing (one third scale) has been started by AV. It will be used for the demonstrator. Copies were given to ACC for reference; of particular interest is the suspension component detail. AES is supplying background criteria information for this and ACC offered to advise on human packaging concerns.

- **Air Flow - Heat Exchanger** - AV is requesting an intake of 1000 cfm (approximately 28.3 cmm) for the heat exchanger. A radiator about 15 inches high by about 19 inches wide will be located in the front end of the car.

- **Plenum** - In the absence of a specific design, ACC is assuming the plenum will have a cross sectional area and intake requirements similar to those of the Fiero.

- **Dash Stack-Up** - At this time the height of the dash has not been determined, but it appears that component stack-up on the motor side will consist of only the plenum, heater/air conditioner, steering column and pedals.

- **Door Glass** - AV's vehicle probably will have framed doors. They want to use as thin door glass as practical for weight purposes and want to make use of the guidance system frames would give.

D Macfarlane

Don Macfarlane

DISTRIBUTION

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MEMORANDUM

TO	John Schinella, Don Macfarlane, Jon Albert, Rick Drumsta
FROM	Alec Brooks
DATE	Feb. 22, 1989
SUBJECT	Under-hood packaging and glass weight
COPIES TO	Howard Wilson, Jerry Williams

I have been following with great interest the development of the full-scale clay model and the mockups for the interior and underhood areas. The entire design team at ACC is to be commended on what is emerging as a very attractive design. At this juncture, I think it is appropriate to step back briefly and review where we are, and how well the overall design is meeting the targets.

The solar load seems to be well under control; the sun load of the current design is better than the target. The aerodynamic drag is still an unknown; the wind weighted drag must be reduced by 15 percent, or 30 counts, in order to meet the target. We won't know until the next round of tunnel tests how far towards this goal the current design will take us. The other big item is weight. As I mentioned in my memo of February 7 to the entire project team, weight control is going to be one of the biggest challenges in the program. Many of the components are coming in above their target weights. It will be necessary for everyone on the team to hold the line on weight if the car is to be a success.

In the sheet that I faxed out on Monday, I outlined where we stand on glass weight (A copy is attached). As you can see, we are 11.9 pounds, or 27 percent over the target for all of the glass. Almost all of the overrun is accounted for by the windshield. In order to understand why the windshield weight is high, we have put together (with the help of AES) a drawing comparing the centerline windshield contours for the current EV design with those for the F, Y, and P cars. All windshield locations are shown relative to a common H-point. A reduced copy of the drawing is attached. Although the angles at the windshield bases are all about the same, the EV windshield is substantially larger than the others due to its curvature. Specifically, it is 15 percent larger than the F-car, 26 percent larger than the P-car, and 19 percent larger than the Y-car.

I had a chance to review the underhood mockup this morning. As you know, the component packaging is extremely tight. We have yet to add the ducting for the motor, inverter and battery box, as well as the compressor for the air conditioning. The inverter box is only 1/2 inch away from the air plenum at the base of the windshield, and the brake master cylinder is inaccessible and hidden from view. Even though we might just be able to squeeze everything in (with the A/C compressor in the passenger compartment), it is my view that the packaging is just too tight. There should be a little bit of breathing room to accommodate those components that might grow, or are unexpectedly added.

In view of the afforementioned concerns, I would like to suggest that you seriously consider the following modification to the vehicle design: move the base of the windshield 5 inches rearward, while leaving the header in the same location. This will result in a windshield cross sectional contour nearly identical to that of the F-car, as shown on the attached drawing. Assuming PPG provides the thinner two-ply glass for the windshield, this change would bring the overall glass weight down to 46.1 pounds, or only 3 pounds above the target. The additional room under the hood would allow considerably greater freedom in packaging and component selection, leading to a lighter and more efficient powertrain installation. This change would result in a minor slope discontinuity where the windshield meets the roof (similar to most cars), but would most likely have no effect on the drag.

I realize this is a major change and would definitely impact the schedule, but I think it is more important to meet the technical goals than to meet the schedule. I hope that you will be able to respond favorably to this suggestion. A written response would be greatly appreciated. Thank you.

Glass Weight Status 2-20-89 ANB

Item	target	current status	notes
Windshield	18.2 lb	28.7	two plies 2mm glass, 0.8mm plastic
door glass	10.4	12.0	3.3 mm glass 0.5 mm plastic
rear quarter	7.4	6.0	"
rear window	7.4	8.6	"
Total	43.4	55.3	

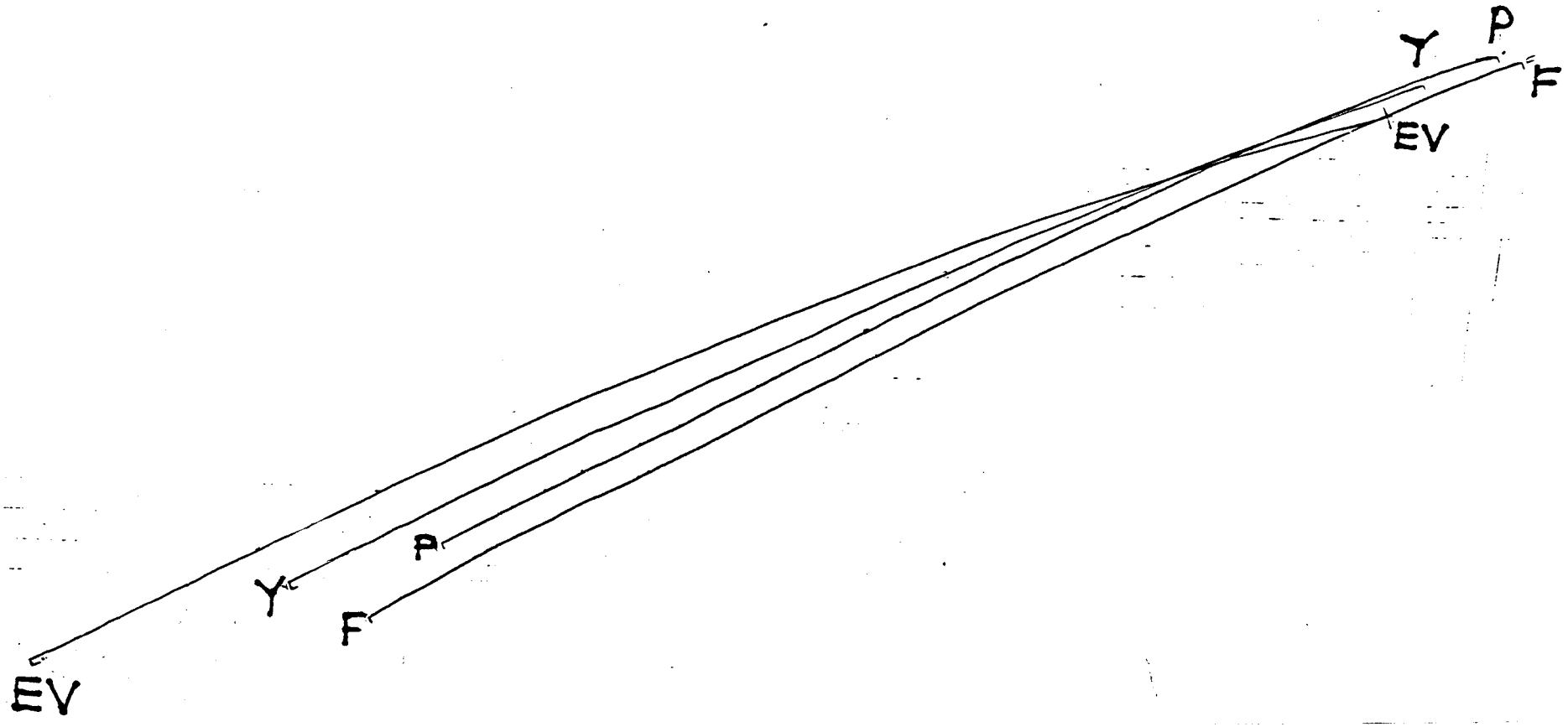
Notes:

assumes linear dimensions are 7% greater than apparent visible glass to account for mounting

B and C pillars assumed to be 140 mm wide

two ply windshield of 3.2 mm glass and .8 mm plastic
saves 18.5 %

thinner side glass of 3.2 mm glass and .5 mm plastic
saves 2.9 %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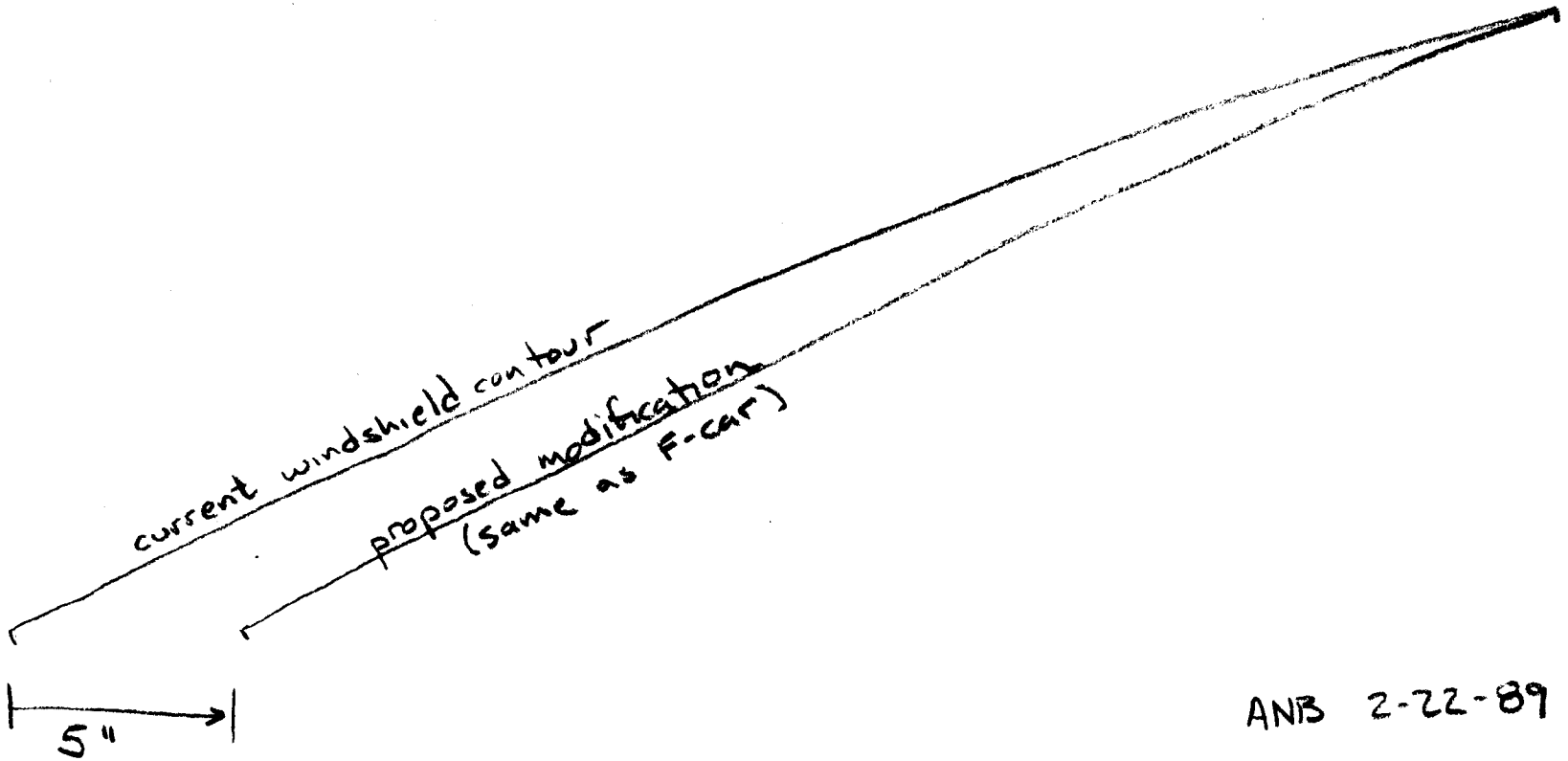
EV


current windshield contour
proposed modification
(same as F-car)
5"

ANB 2-22-89

MEMORANDUM

TO	Jon Albert
FROM	Alec Brooks
DATE	March 3, 1989
SUBJECT	Drag vs. Weight
COPIES TO	John Schinella, Don Macfarlane, Howard Wilson, Jerry Williams

Congratulations on your excellent results in the most recent round of wind tunnel development work! I understand that a wind-weighted drag coefficient of 0.189 has been achieved (including external mirror). With the four-count addition for real-world full scale correction, the target of 0.192 is essentially met.

I realize that the car had to be lengthened by about eleven inches in order to achieve the drag target. We have estimated that this will increase the overall weight by about 30 pounds. In this case, the increased weight is more than compensated for by the reduced drag (in terms of driving range). Acceleration will suffer only slightly due to the additional weight (0.1 second for 0 to 60 mph).

Attached is a summary drag and weight trades that Taras has put together. Note that the range trade off of 10 pounds for each Cd count means that the loss of range due to 10 pounds of added weight would be exactly balanced by a one-count decrease in drag. Obviously, it would only be sensible to make a weight increase / drag decrease tradeoff if the weight increase was substantially less than 10 pounds per drag count.

Weight-Drag Tradeoffs

In order to meet the driving range goals of the Santana electric vehicle program it is necessary at this point in time to review the impact of weight and aerodynamic drag on vehicle performance.

The proposal submitted to General Motors on 22 July 1988 specifies the following performance figures:

Urban Range (no A/C)	133 mi.
Suburban Range (no A/C)	131 mi.
Highway Range (no A/C)	129 mi.
Urban Range (max A/C)	71 mi.
Suburban Range (max A/C)	98 mi.
Highway Range (max A/C)	104 mi.
0 to 60 Time	8 sec.

Wind tunnel tests conducted in early April at the GALCIT 10' facility on a variety of aerodynamic configurations showed that it is possible to meet the range targets listed above.

However, the configurations that showed sufficiently low aerodynamic drag to meet the target were somewhat longer than the original layout, having more rear overhang. This adds weight to the car. A rear diffuser wing was found to be aerodynamically beneficial, but also adds weight.

The tradeoffs between aerodynamic improvement and weight must now be addressed to reach a finalized design.

Computer simulations of driving cycles yield the following results (no A/C):

- The effect of weight is to decrease range by one mile for each additional 40 lbs of weight.
- The effect of aero drag is to decrease range by one mile for each additional 4 counts of drag coefficient.
- Thus the range trade off is 10 lbs for each Cd count.

From the standpoint of driving range, relatively small reductions in aero drag justify significant weight increases.

Additional weight hurts acceleration and handling, which slants the 10 lb /1 count tradeoff somewhat (each additional 30 lbs increases 0 to 60 time by 0.1 seconds).

Modifications that increase weight and increase aero drag must be avoided!

MEMORANDUM

TO Howard Wilson, Jerry Williams

FROM Alec Brooks

DATE March 3, 1989

SUBJECT Follow up on requested windshield changes

By now you should have received a copy of Don Macfarlane's response to my memo of Feb. 22. A copy is attached in case you haven't. I have also attached current drawings showing the baseline car and the car with the modified windshield which is "not aesthetically acceptable".

As shown in the attached drawings, the windows have been reduced in size by rounding all of the edges. The new glass weight estimate is 51.9 pounds with the standard PPG glass, or 46.4 pounds with the thinnest PPG glass. The glass weight target is 43.4 pounds. The windshield change that I had requested would have brought the weight down to 46.1 pounds.

The underhood component crowding is still a problem, but I believe that we will be able to fit everything in. However, it is my judgement that the packaging is too tight.

Advanced Concepts Center General Motors Corporation 2193 Anchor Court Newbury Park, California 91320

February 27, 1989

Mr. Alec Brooks
AeroVironment
825 Myrtle
Monrovia, CA 91016

RE: Underhood Packaging and Glass Weight

Alec:

Thank you for your suggestion concerning moving the base of the winshield rearward for glass weight reduction and underhood packaging considerations. We have made a layout of the proposed windshield centerline and compared it to what is currently on the clay model. The resulting shape change is not aesthetically acceptable.

We do share your concern about vehicle weight, though, and realize the contribution the glass is making to the overage. With this in mind, we are reviewing the size of glass panels and their related openings as the full size design progresses. Weight is being reduced as glass overlap of metal around openings is minimized and glass is eliminated from areas where it is not required for visibility. We will keep you informed on our progress in this area.

With respect to underhood component crowding, perhaps ACC people should participate in that area more directly. I am not suggesting long term, general involvement, but Rick Drumsta has had some experience with this sort of thing during previous assignments. He could review your plans with AeroVironment people on a team basis and possibly make some suggestions to relieve the crowding to some extent.

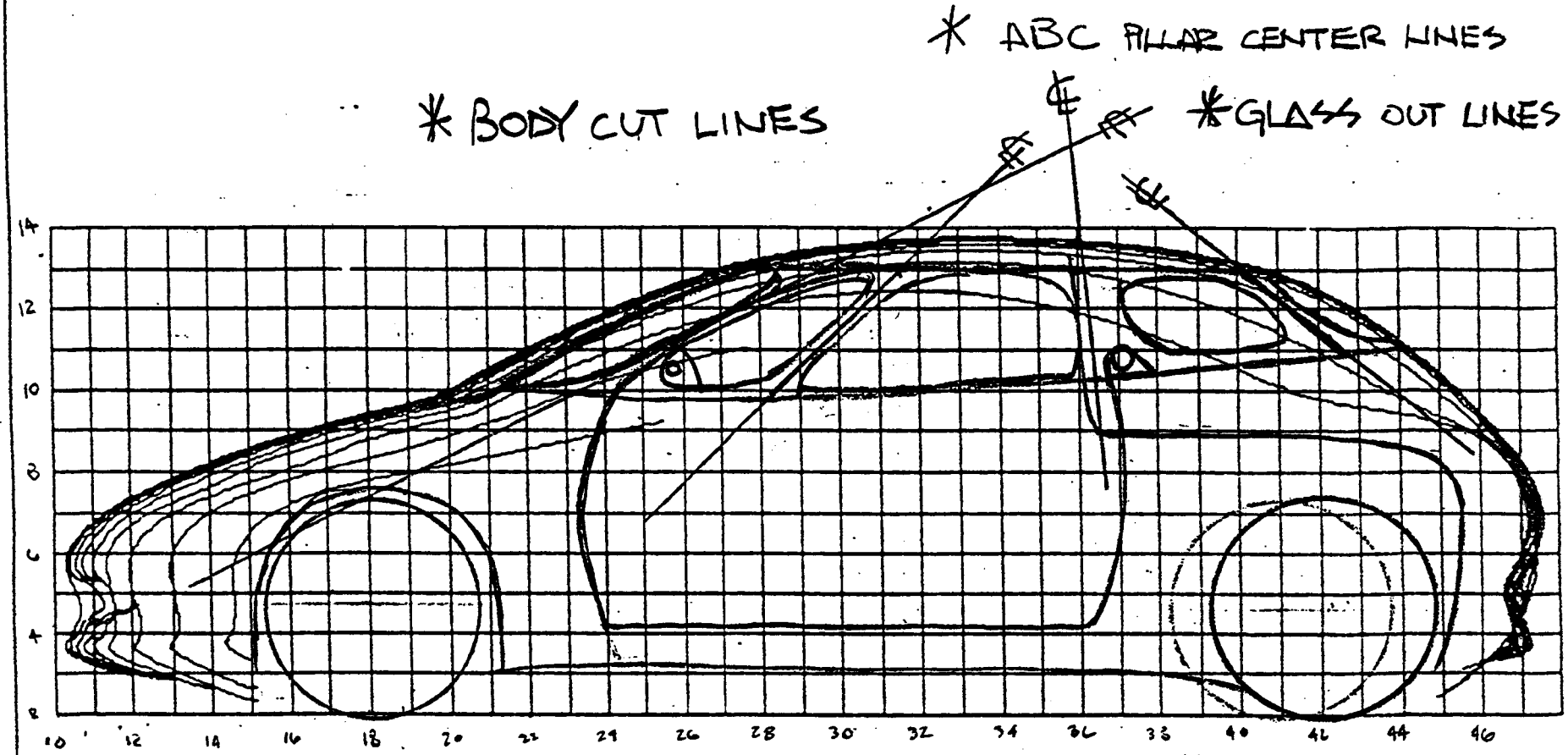
Sincerely,

Don Macfarlane
Mgr. Engineering &
Design Services

DM/dh
cc: J. Albert
J. Bieck
R. Drumsta
J. Schinella
J. Williams
H. Wilson

DATE: 01/16/89 TIME: 16:02:15 NAME: ECSV2

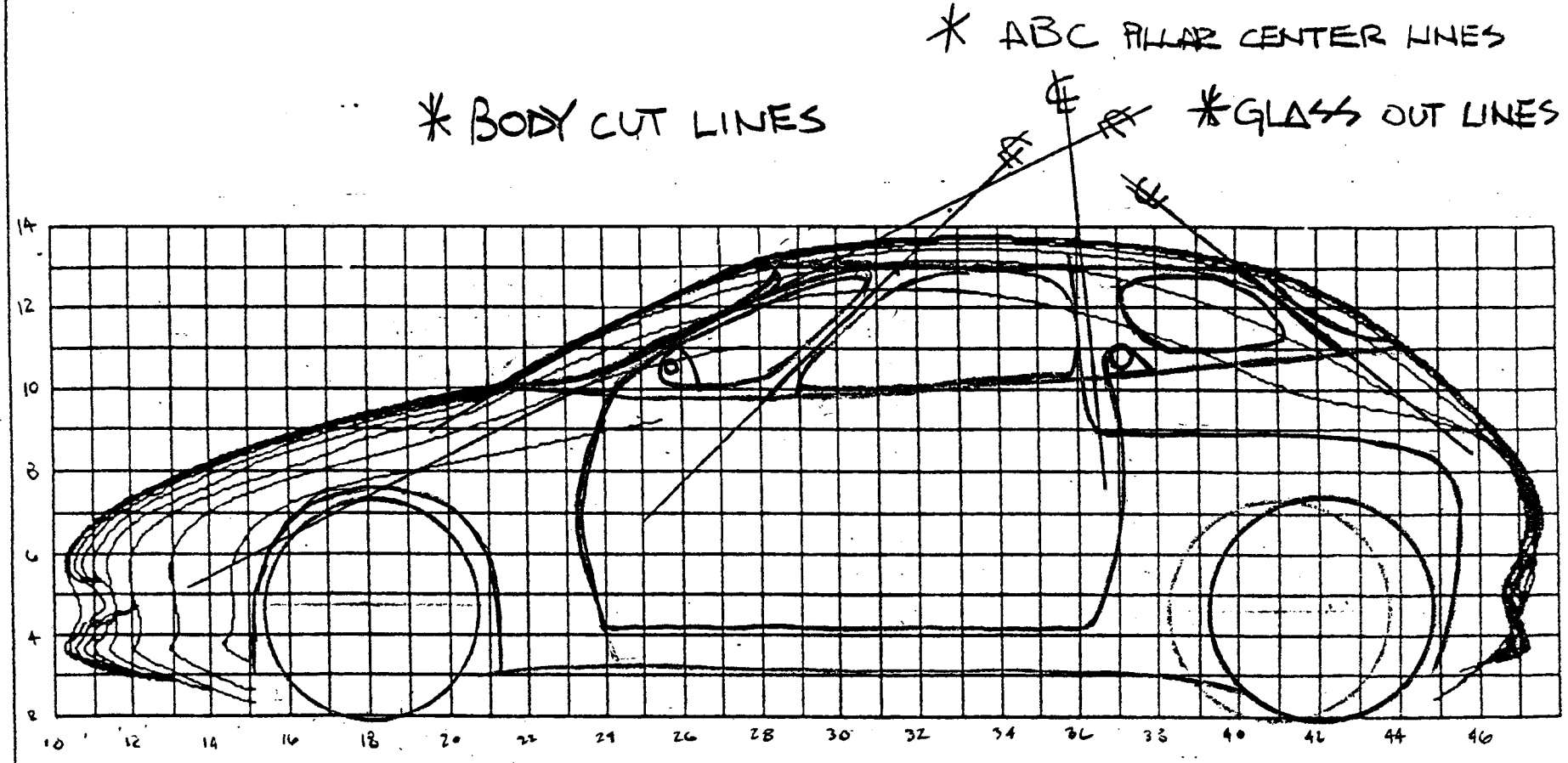
DB 3.7.89



ACC / EV:

DATE: 01/16/89 TIME: 16:02:15 NAME: ECSV2

DB 3.7.89



Mod. suggested by ANB Feb 22

ACC / EV: