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FUTURE POTENTIAL AND INTER-MATERIALS COMPETITION IN LIGHTWEIGHT AUTOMOTIVE COMPOSITES

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Abstract – Lightweight, fiber reinforced thermoplastic (LF-RTP) composites, based primarily on polypropylene and glass fibers, are in the growth stages in automotive and other markets based on their ability to provide semi-structural properties, light weight, and cost savings. This paper will provide an overview of recently introduced automotive composites and examine:

- Automotive driving forces propelling market growth
- How performance affects market potential
- The position of lightweight composites in the family of composite candidates
- Competition from non-composites such as:
  - Advanced nonwovens
  - Foams
  - Hybrids (metal/plastic)
  - Unfilled plastics
- Intra-composite competition
- Shifts in composites industry structure.

The presentation is based on REA's:

- Recent automotive composites research in Europe, North America and Japan
- Recently completed automotive interior soft trim study (1)
- Planned second global TPE multiclient study (2)
- Multiclient analysis of advanced technology nonwovens in the automotive sector (3).

References and abbreviations are included at the end of this paper.

The Automotive Composite Families – During our consulting work in the automotive composites sector, it has become apparent that:

- New composite classes are emerging
- Competition between composite classes will intensify
- The lines between application classes are becoming blurred as functions are integrated onto modules
- Composites encounter new classes of competitors as density decreases.

To develop a comprehensive view of the competitors in the automotive composites sector we, therefore, developed the organogram shown in Exhibit 1, which identifies the classes of composites and can serve as a starting point for the analysis of intra-composite competition.

Some of the operating hypotheses for our analysis in this paper are shown in Exhibit 2.

Automotive Economics/Industry Structure Effects on Composites – We have documented elsewhere (References 1-4) the effects of current automotive market conditions on material and process substitution as well as on supply chain structure shifts. Market and economic pressures on automotive OEMs are transferred to their materials and module suppliers and are stimulating technology innovation in both fabrication processes and materials. The current automotive economic/materials technology interface can be summarized as follows:

- Slow emergence from recession conditions.

- Severe profitability squeeze on Tier 1s from OEM customers and raw material price increases. This provides incentive for composite substitution to integrate components and provide materials and process innovations capable of adding value while providing cost savings.

- Rapid growth of global parts sourcing and the growing role of China as materials supplier and assembled parts supplier.

- Tier 1 consolidation has created a substantial increase in purchase power (pressuring prices downward) as well as incentives for in-house compounding by fabricators. The most notable example in the composites sector is in long-glass fiber reinforced PPs (LGF-PPs).

- The continuing market share loss by domestic automotive North American OEMs to non-domestic competition is stimulating the entry of Japanese and European vehicle technology (front end modules, seat components, headliners, wheel arch liners, floor modules are examples).

- High volume (sometimes global), multi-vehicle platforms have increased, raising the stakes for successful participation. There are now approximately twenty platforms in the global fleet with vehicle volumes of 1-2.5MM units.

Composites Industry Structure and Supply Chain Shift – The automotive supply chain must change in order to accommodate current profitability, competitive, legislative and vehicle performance pressures. The composites supply chain as well as other plastics and rubber supply chains are shifting. For composites, the changes are more severe due to the entrance of new materials and process competitors and suppliers. The structure of the automotive composites industry is changing as:

- Compounders are broadening their product lines
- Fiber and nano-composite concentrates are being offered to specialty compounders and major fabricators
- Technology for direct compounding/fabrication of LGF-TPs has proliferated
- New materials (e.g., natural fibers, biopolymers, nano-composites) candidates enter the supply chain
- Modularization encourages integration of components via the use of composites
- Composites enter new vehicle modules and functions (semi-structural headliners and floor module elements, for example).

Some of the composites supply chain key changes are listed in Exhibit 4.

Intra-composite Competition -- As the range of materials and process possibilities has increased, competition between composites (intra-composite competition) has intensified beyond the well-known competition between thermoset and thermoplastic matrices.

Some examples of emerging intra-composite competition are:

- LD-RTPs displacing HD-RTPs in semi-structural applications
- Nano-composites replacing mineral-reinforced TPOs and ETPs (in bumper fascia and electronics components)
- Nano-composites and LGF-PPs competing for running boards and step pads
- Nano-composites competing with LGF-PPs for body side moldings.

The broadening of the property range of composites, especially the lowering of density, has brought them into competition with established and emerging materials classes. Some examples of competition between composites and other materials classes are:

- LD-RTPs competing with multi-layer nonwoven sandwiches and compression molded sheet in wheel arch liners
- LD-RTPs competing with foam/skin laminates in floor modules
- LD-RTPs displacing PU foams in headliners
- Nano-composites use multi-layer, coextruded sheet in thermoformed fuel tanks
- Nano-composites competing with PVC for body side moldings.

Emerging Auto Applications -- Illustrations of emerging applications for automotive composites are shown in Exhibit 3. The competition between composites for these applications is shown in the summary table of Exhibit 5.

Low Density Glass Mat Thermoplastics -- High density GMTs (density range, 4000-5000grams/sq. meter) are a mature thermoplastic composite for structural applications (e.g., for bumper reinforcing beams). In semi-structural applications, they have been displaced by a range of alternatives including LD-GMTs with densities in the 700-2000 gsm range. LD-GMTs from several suppliers (Quadrant, Azdel, Owens Corning, several Japanese suppliers) are in the early rapid growth stages. Applications have been described previously at this Automotive Composites Conference and in several papers (References 7, 8).

A competitive interface has been established between foams, LD-GMTs, and regenerated fiber mats as the density of the LD-GMTs decreases. As illustrated in Exhibit 6, there is no significant competition between LD-GMTs and LGF-TPs.

Headliner Supports -- LD-GMTs have made deep penetration into headliner supports in N. America, Europe and Japan vs. glass fiber reinforced PU foams. The headliner support is a good example of the new generation of semi-structural composites applications because it:

- Requires energy absorption (to meet FMVSS 201)
- Opens the potential for integrating foams and energy absorbing elements into the support
- Competes with foam core solutions
- Requires acoustic performance (therefore opening the opportunity for advanced technology nonwovens) (see Reference 4)
- Integrates textiles (nonwovens and knits)
- Offers a variety of trim options
- Brings new suppliers into the supply chain
- Places high priority on space conservation
- Offers value-added potential and layer integration potential in a low profit module.

Underbody Shields – Underbody shields based on LD-GMTs are well established in European high end vehicles, starting in the mid-'90s. Penetration has extended to mid-level vehicles in the European fleet but there is yet to be a substantial penetration into the N. American market.

Wheel Arch Liners -- can be made from a range of reinforced and non-reinforced sheet. In Europe, constructions based on nonwoven/filled sheet/nonwoven sandwiches (e.g., from San Valeriano) (see Reference 4) have penetrated the market in competition with LD-GMTs.

Fiber Reinforced Composites – Short-glass fiber reinforced thermoplastics (SGF-TPs) are the major incumbent in the fiber reinforced thermoplastics (FR-TP) class of composites (see Exhibit 1).

LGF-TPs: The long-glass fiber thermoplastics, offered by an increasing number of suppliers, extend the property range of the SGF-TPs for structural and mechanical applications.

Example applications include:

- Front end modules (note competition with hybrids and HD-GMT)
- Running boards (note competition with nano-composites)
- Door module (competition with SGF-PP and ETPs)
- Load floors (note competition with LD-GMTs and foam sandwiches)
- Instrument panel substrates.

The LGF-TPs offer an example of how the composites supply chain is shifting. Equipment introduced by Dieffenbacher and others allows the compounding and direct (in-line) fabrication of components. Such equipment to make direct LGF-TPs (D-LGF-TPs) has been installed by both:

- Large Tier 1s (e.g., Faurecia and Johnson Controls)
- Mid-sized custom automotive molders.

The cost benefits of avoiding the pelletizing step via in-line compounding have been reported by equipment suppliers and contested by compound suppliers.

Masterbatches with high concentrations of long glass fibers are also available from compounders for letdown by either specialty compounders or molders.

Compounds, masterbatches, and D-LGF-TPs are competing paths to market. All are likely to participate and it is too early to predict the shares. It is clear, based on the number of D-LFT machines sold, that the direct process has and will continue to gain a major share, especially among large processors with long runs.

Self-reinforced Composites: It is possible to produce high tensile strength fibers via stretching. Tensile strength increases roughly in proportion to draw ratio. By controlling the position of the fibers in the matrix or via lamination, it is possible to make self-reinforced composites with PP and PET. PP self-reinforced composites are offered by several sources and are targeted at some of the same applications as LD-GMTs and LGF-PPs. The cost disadvantage of the self-reinforced PP composites may limit their market penetration potential.

Natural Fiber Reinforced Composites (NFCs) -- Natural fiber reinforced composites based on wood fibers are widely used in auto interior applications in both thermoplastic matrices and with thermoset binders (e.g., phenolic). Thermoplastic matrix composites have gained share at the expense of phenolic binder composites. (Recently wood fiber reinforced PPs have had a growth spurt in non-auto applications, especially building/construction.)

Hemp, jute, kenauf and other bast fibers have been widely discussed as the reinforcing fiber (usually in PP) but have not yet grown significantly. Some OEMs have shown interest in back integrating to fiber plantations in order to protect sources and quality.

While incorporation of natural fibers in a hydrocarbon (HC) matrix is of interest, incorporation of natural or biopolymers in a biopolymer matrix based on renewable sources is of even greater interest. Polylactic acid (PLA) from corn appears to be in the lead as a biopolymer candidate. The investment by Toyota in a 1000 tpy facility suggests a serious commitment targeted at interior components. Research at Michigan State and the University of Washington into synthesis of polyhydroxy alkynoates (especially PHB) yields long chain polymers via controlled fermentation, which may have promise as a matrix resin. When functionalized with maleic or succinic anhydride and reinforced with fibers such as hemp or hennequin a biopolymer composite is obtained. This work appears to be at the polymer characterization stage but shows some promise. The economics remain to be defined.

Mineral Reinforced Thermoplastics/Role for Nano-composites -- Mineral fillers have been incorporated into thermoplastic matrices to increase heat resistance and stiffness since the earliest days of automotive plastics. The physics of incorporating relatively large particles (often with agglomerates) dictate a battle between the positive benefits of improved stiffness and heat resistance and the deterioration of other properties (impact strength, processability, surface characteristics, etc.).

Nano-sized mineral fillers offer the capability of making mineral-TPs (nano-composites), which achieve the benefits of filler addition at lower concentrations (e.g., 3-5% vs. 12-40%), thereby:

- Avoiding the damage to the composite morphology that results from conventional-sized filler particles

- Gaining the benefits of lower density and lower filler concentration
    - (Potentially) lower volumetric costs
    - Easier processability (higher polymer content, less viscosity increase)
    - Wider processing window (reduces scrap rate)
    - Thin wall molding capability

- Unexpected benefits (improved scratch/mar resistance, lower CLTE, better dimensional tolerance)

Thus far, the major automotive target has been clay/TPO nano-composites. Four well-known parts are already on cars at GM, including:

- Body side moldings (note competition with PVC and LGF-TPs)
- Step assist (note competition with LGF-PP)
- Exterior components (on the Hummer H-2).

TPO appears to be the major host resin in which the benefits for applications such as body panels and fascia could be of interest. At the current cost levels, it is unlikely that nano-PPs will be competitive with talc-PPs across a wide range of applications.

Nylon was the first generation of nano-composite matrix (Toyota in the late '80s) targeted at fuel and under-hood applications. Recently there has been renewed interest in nylon and other ETPs in high tolerance parts like electrical connectors (note increased demand, higher heat requirements and higher electrical performance from 42 volt automotive systems).

The high surface area coverage obtained with nano-minerals results in an increase in vapor barrier properties. Nano-composites (possibly in HDPE matrices) are likely to play a role in the anticipated growth of the thermoformed fuel tank.

Some examples of target applications for nano-composites are shown in Exhibit 7.

Clay is the dominant incumbent nano-mineral at present, but nano-talc offerings are reaching the market (from Nanova and possibly others) and may offer competitive advantages (less energy for exfoliation).

SUMMARY

The field of automotive composites is broadening rapidly and will experience rapid growth in exterior, interior, and under the hood structural, semi-structural, non-structural and mechanical applications.

The LD-GMTs will grow with the evolution of more complex, large area modules and components (headliner, floor modules, seat components and underbody shields are examples). The ability to incorporate on-board energy absorption, acoustics, and esthetic functions enhance the value added potential of the LD-GMTs.

The new generations of automotive composites will compete with each other (intra-composite competition), and their expanded property envelope brings them into competition with a broad range of non-composite competitors (especially foams).

Automotive price pressure will continue to stimulate:

- Composite penetration into larger, more cost effective modules
- Value-added opportunities for composites materials suppliers and fabricators
- Shifts in the composite supply chain.

Biopolymers are in an early stage in their penetration of the automotive composites sector. Their potential remains to be defined.

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See other publications on REA web site: www.robertellerassoc.com

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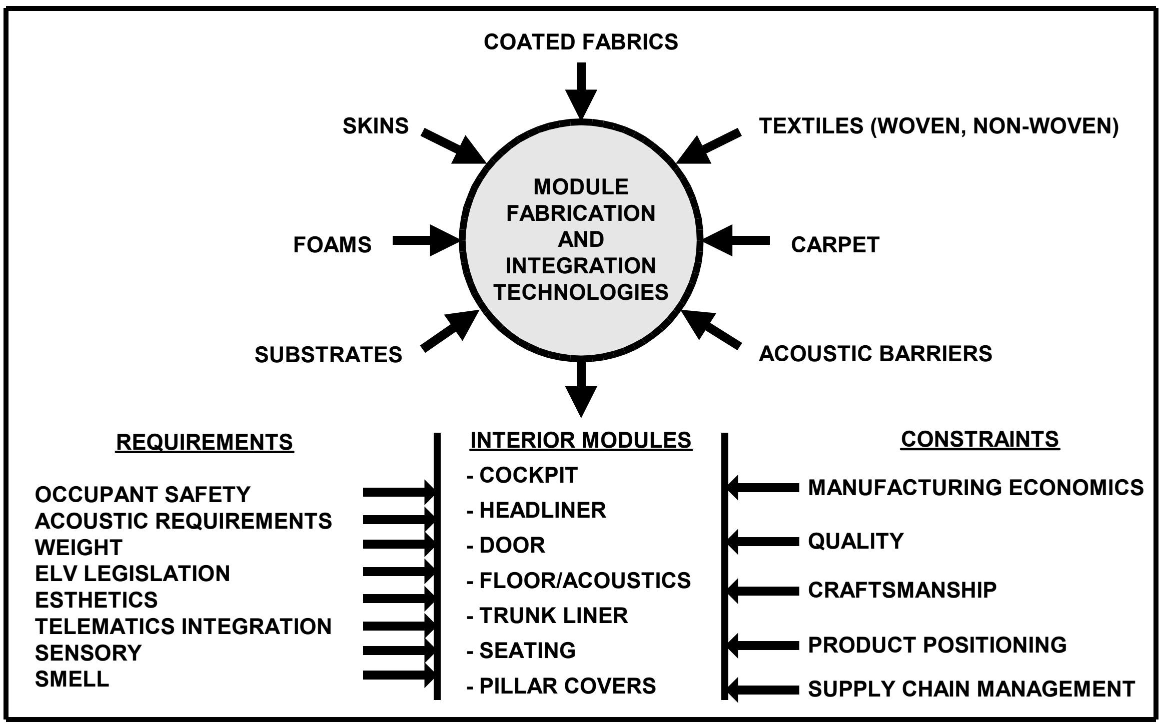
ABBREVIATIONS USED IN THIS PAPER

BIO-NFC	- biopolymer matrix natural fiber composite
D-LFT	- direct long-fiber thermoplastics
D-LGFPP	- direct long-glass fiber polypropylene
DT	- door trim
ETP	- engineering thermoplastic
FEM	- front-end module
FLR	- floor
GMT	- heavy glass mat thermoplastic
HC-NFC	- hydrocarbon-matrix natural fiber composite
LD-RTP	- low density reinforced thermoplastic
HD-GMT	- high density GMT (e.g., Azdel)
LFR-PP	- lightweight fiber reinforced polypropylene
LFR-TP	- lightweight fiber reinforced thermoplastics
LGF-PA	- long-glass fiber reinforced polyamide
LGF-PP	- long-glass fiber reinforced polypropylene
LGF-TP	- long-glass fiber reinforced thermoplastic
MB	- masterbatch
MIN-TP	- mineral filled thermoplastic (e.g., talc/PP or talc/TPO)
MM	- million
NANO-TP	- nano-composite thermoplastic
NFC	- natural fiber composite
SGF-PP	- short-glass fiber polypropylene
SGF-TP	- short-glass fiber thermoplastic
SIM	- sequential injection molding
UB	- under body

Automotive Interior Soft Trim:

Skins, Foams, Coated Fabrics, Textiles, and Acoustic Barriers



A Europe / North America Multiclient Analysis (March, 2003)

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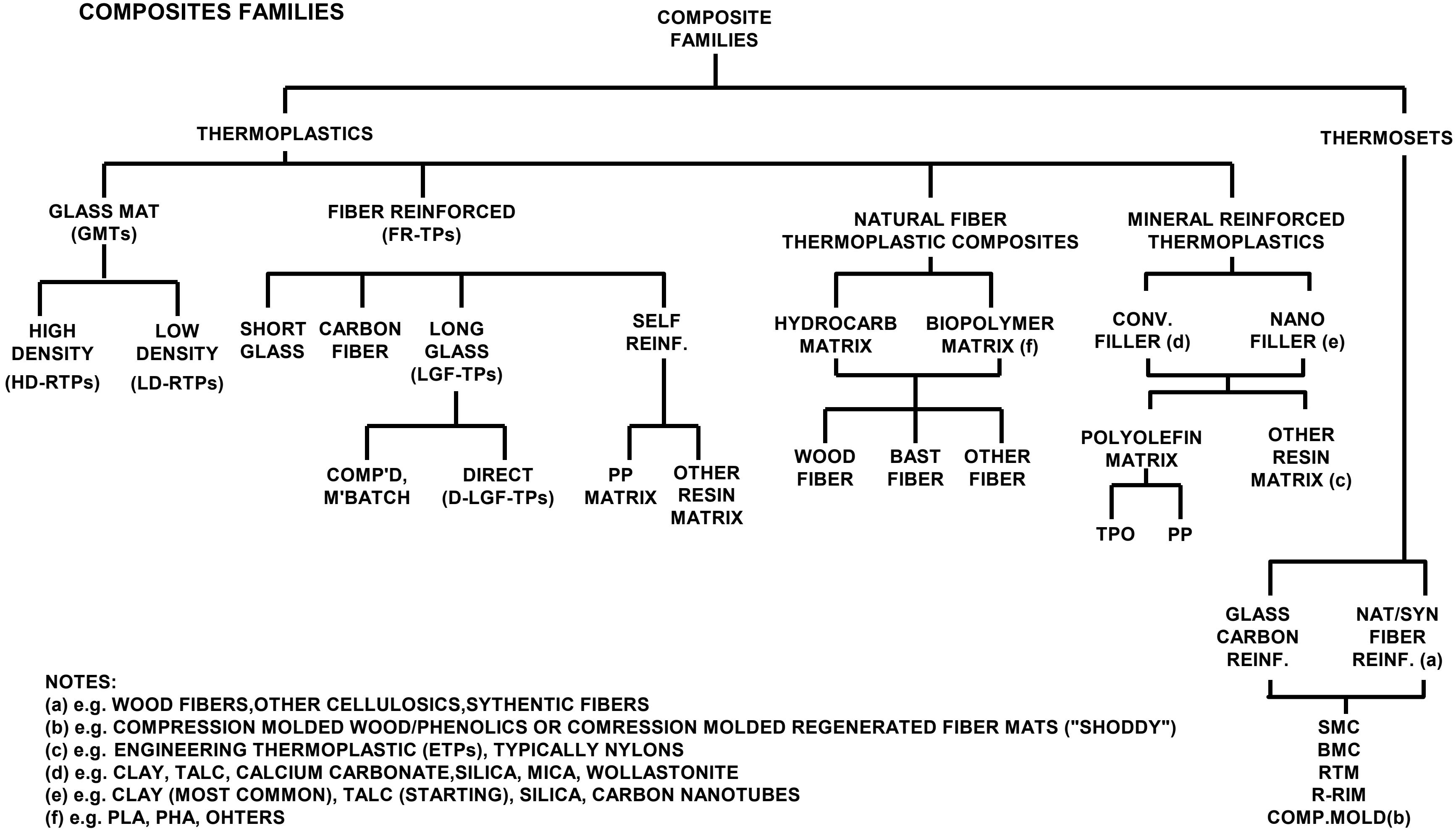
EXHIBIT 1

COMPOSITES FAMILIES



NOTES:
(a) e.g. WOOD FIBERS,OTHER CELLULOSICS,SYTHENTIC FIBERS
(b) e.g. COMPRESSION MOLDED WOOD/PHENOLICS OR COMRESSION MOLDED REGENERATED FIBER MATS ("SHODDY")
(c) e.g. ENGINEERING THERMOPLASTIC (ETPs), TYPICALLY NYLONS
(d) e.g. CLAY, TALC, CALCIUM CARBONATE,SILICA, MICA, WOLLASTONITE
(e) e.g. CLAY (MOST COMMON), TALC (STARTING), SILICA, CARBON NANOTUBES
(f) e.g. PLA, PHA, OHTERS

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004
compconf0n.vsd

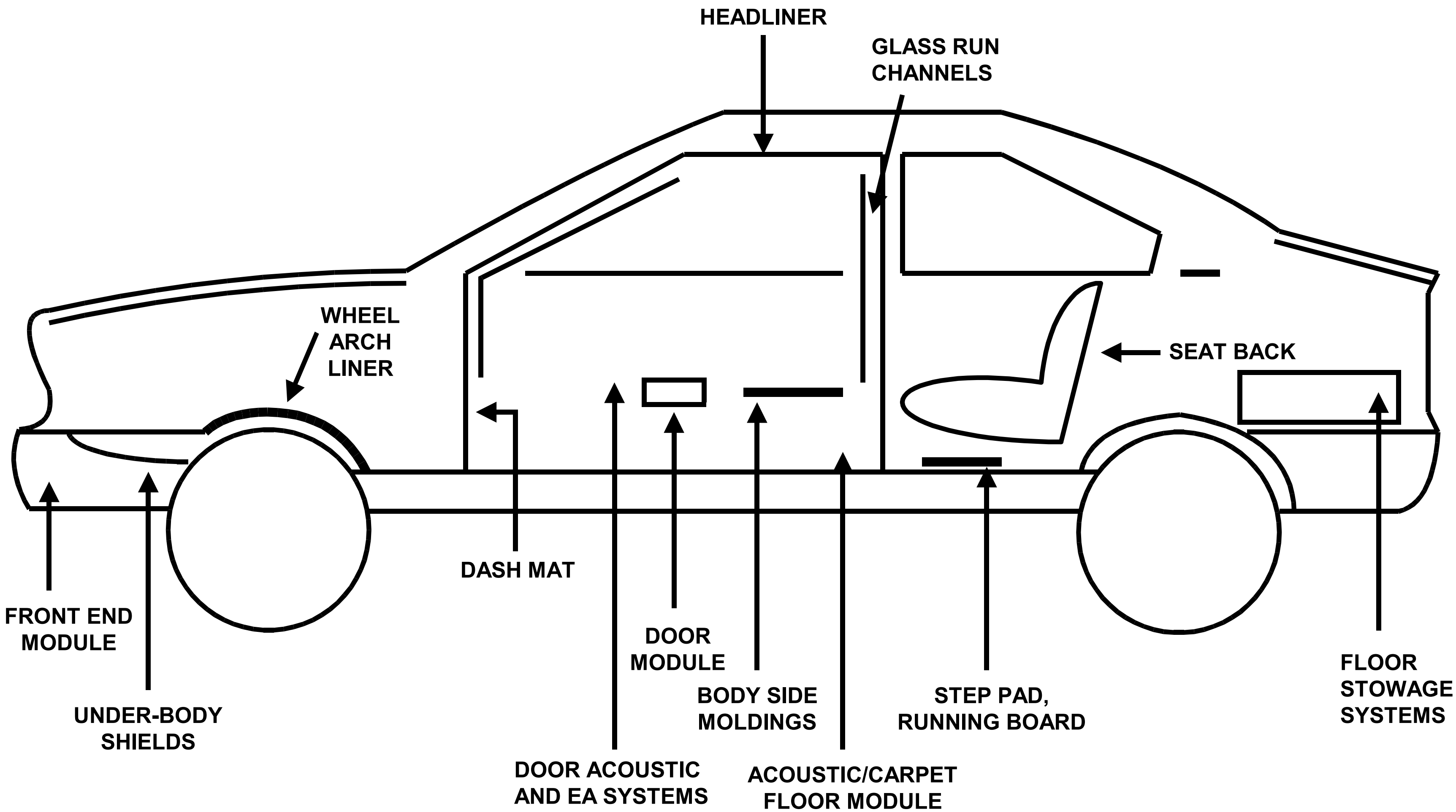
EXHIBIT 2

OPERATING HYPOTHESES AFFECTING AUTOMOTIVE COMPOSITES

- Automotive composite target classes include:
  - Structural (e.g., cross-car beams, flooring, roofing)
  - Semi-structural (e.g., floor module, headliner)
  - Mechanical
  - Non-structural (e.g., seat backs).
- There is inter-material and inter-process competition between auto composite candidates.
- Energy absorption functional requirements will drive increased composites usage in both interiors and exteriors.
- Acoustic and energy absorption functions will be integrated with functional components.
- Thermoplastic matrices will be used where possible.
- Weight savings incentives will increase.
- Space savings are valued in headliner and door trim.
- Natural fibers can compete in semi-structural applications.
- Decline in use of glass fiber reinforcement in light weight, semi-structural composites.
- Continued growth of "tall cars" will stimulate growth of composites in floor modules.
- Floor modules will become larger, more complex, and demand higher levels of craftsmanship.
- European growth of FEMs will continue to accelerate, become a factor in N. America, and stimulate the growth of composites.
- The structure of the auto composites supply chain will shift to eliminate intermediate steps.
- Biomaterials could enter the automotive supply chain as fibers and matrices in composites.
- Automotive nano-composite technology and commercial application is more advanced in N. America than in Europe.

EXHIBIT 3

COMPOSITES TARGETS



SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

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EXHIBIT 4

AUTO COMPOSITES INDUSTRY STRUCTURE SHIFTS

- HEAVY GMT SUPPLIERS ENTER LIGHT WEIGHT GMT
- GLASS FIBER SUPPLIERS ENTER LGF-TP COMPOSITE PRODUCTION
- COMPOUNDERS ENTER NANO-COMPOSITE AND LGF-TP CONCENTRATES
- DIRECT COMPOUNDING OF LGF-TPs BY:
  - CUSTOM AUTO MOLDERS
  - BACK INTEGRATED TIER 1s
- ENTRY OF NATURAL FIBERS PRODUCERS (SOME VIA BACK INTEGRATION BY AUTO OEMs AND TIER 1s)
- EMERGENCE OF BIOPOLYMER SUPPLIERS

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

EXHIBIT 5

INTRA-COMPOSITE COMPETITION FOR AUTOMOTIVE APPLICATIONS

APPLICATION	THERMOPLASTIC COMPOSITE CANDIDATES							
	LD-RTP	HD-GMT	SGF-TP	LGF-TP	HC-NFC	MIN-TP	NANO-TP	OTHER (a)
ACOUSTIC BARRIERS	X							X
BODY SIDE MOLDINGS				X		X	X	X
BUMPER FASCIA						X	X	X
DOOR TRIM PANELS					X	X	X?	X
DOOR MODULES	X	X?	X	X				
ELEC. CONNECTORS			X				X	X
FLOOR MODULES	X	X			X			X
FRONT END MODULES		X(b)		X				X
FUEL LINES							X	X
FUEL TANKS							X	X
HEADLINER	X							X
IN-MOLD DECORATION							X	X
INTERIOR SKINS							X	X
IP SUBSTRATES				X	X	X		X
MECHANICAL COMPONENTS			X			X	X?	X
ROCKER PANELS						X	X	X
RUNNING BOARDS				X			X	X
STEP PADS				X			X	X
WHEEL ARCH LINER	X					X		X

NOTES:

SEE GLOSSARY OF ABBREVIATIONS

DOES NOT INCLUDE THERMOSET MATRIX COMPOSITES

(a)OTHER INCLUDES NON-COMPOSITE COMPETITION FROM:
- FOAMS
- REGENERATED FIBER MATS (“SHODDY”)
- NONWOVENS
- UNFILLED POLYMERS (PRIMARILY ETPs, PVC)
- FOAM/SKIN LAMINATES
- THERMOSETS (PU, POLYESTER)
- METAL/PLASTIC HYBRIDS

(b)HD-GMTs HAVE LOST SHARE IN FEMs

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004 (References 1, 3)

EXHIBIT 6
COMPARISON OF LD-GMTs AND LGF-PPs

PARAMETER	LGF-TP	LD-GMT
DENSITY, GSM		LOWER, 700-2000(a)
TOOLING COST		LOWER(b)
TYPICAL PROCESS	INJECTION, COMPRESSION	COMPRESSION, THERMOFORMING
TYPICAL GLASS CONCENTRATION, %	40,32	40-55%
DIRECT COMPOUND/ FABRICATION POSSIBLE	YES, COMMON	YES, POSSIBLE; NOT COMMONLY USED
TYPICAL PART	COMPLEX	SIMPLE
PART SIZE	SMALL	LARGE
PART THICKNESS	THICKER	THINNER
USE IN LAMINATES	USUALLY NOT	YES(c)
EXAMPLE APPLICATION	MECHANICAL(d), SEMI-STRUCTURAL(e)	WHEEL ARCH LINER, HEADLINER(f), UNDERBODY SHIELDS
LOAD BEARING CAPACITY	HIGHER	

NOTES:

(a) LD-GMTs CAN BE LOFTED TO REDUCE DENSITY

(b) ALUMINUM OR EPOXY TOOLS CAN BE USED

(c) FOR EXAMPLE IN FLOOR MODULES

(d) E.G., DIE CAST METAL REPLACEMENT

(e) E.G., RUNNING BOARDS (NANO-COMPOSITES COMPETE IN THIS APPLICATION)

(f) ALSO OTHER INTERIOR SEMI-STRUCTURAL APPLICATIONS

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004

EXHIBIT 7

TARGET AUTO APPLICATIONS FOR NANOCOMPOSITES (EXAMPLES)

TARGET	KEY PROPERTIES	STATUS	NOTE
Exterior:			
BODY PANELS	STIFFNESS, PAINTABILITY, THIN WALL	SEVERAL AT GM	HIGH GROWTH POT'L.
GLAZING	LIGHT TRANSMISSION SCRATCH RESISTANCE WEATHERABILITY	EXTENSIVE PRIOR DEVELOPMENT	TARGET FOR GE/EXATEC
BUMPER REINFORC-ING BEAM	STIFFNESS, IMPACT	CONCEPT	
STEP/RUNNING BOARDS	STIFFNESS	STARTED ON GM VANS IN 2002	GROWTH APPLICATION FOR LONG GLASS PP
MIRROR HOUSING	WEATHERABILITY, PAINTABILITY, IMPACT	ABANDONED	TOO EXPENSIVE VS. INCUMBENT
INTERIOR:			
FIBERS	LOW DENIER	TORAY INTRODUCTION	NANO-CARBON
STRUCTURAL SEAT BACK	IMPACT	STARTED AT HONDA	EUROPEAN "BEER CRATE" LEGISLATION WILL DRIVE
SIDE IMPACT BEAM	IMPACT, STIFFNESS	CONCEPT	
TRIM(a)		CONTRACT IN PLACE	EUROPE
UNDERHOOD/FUEL:			
FUEL TANK	BARRIER	GROW WITH THERMOFORMING	REPLACE EVOH?
FUEL LINE	BARRIER	COMMERCIAL IN JAPAN	-EARLY APP. IN NYLON -NANO-ACETAL (JAPAN)
ENGINE COVER		MITSUBISHI ON GDI MODELS	POOR IMPACT RESULTS AT BASF
TIMING BELT COVER	HEAT RESISTANCE	ABANDONED	

NOTES:

(a) FORD (UK) TARGETING PILLAR TRIM, DOOR TRIM PANELS, CONSOLES, AIRBAG DOORS

SOURCE: ROBERT ELLER ASSOCIATES, INC., 2004