Analysis of CACRC Charter

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Introduction

• The CACRC is chartered to solve some significant industry problems
• These problems are systemic in nature and not any “one’s fault”
• We need to understand the system to solve these problems
• Necessarily focused on the negative but there is good too
CACRC Bylaws

• Problem
  “… high maintenance, inspection and repair cost of composite aircraft structure.”

• Charter
  “… to lower the cost of ownership of composite aircraft structure, while enhancing safety.”
Basic Principles

- Knowing **what** to change requires a thorough understanding of the system’s current reality and its goal.
- All systems operate in an environment of cause and effect; something causes something else to happen.
- Most of the undesirable effects within a system are caused by a few core problems.
- Core problems are usually perpetuated by a hidden or underlying conflict.
The Current Reality Tree

- Helps identify what to change
- Examines the cause-and-effect logic behind the current situation
- Links undesirable effects seen in the system to a few root causes or a single core problem
Sufficiency Based Logic

*If* this *and (or) this* *then* that.

The validity of the cause-effect relationships depends on sufficiency. Is this enough (sufficient) to cause that?
Diagram Nomenclature

Undesired Effect

Fact-of-Life

Desired Effect

Cause-Effect Arrow

Or

Necessary Condition Arrow

Logical “And”

Or

Sufficiency

Conflict Arrow

Action,
 Objective or
 Injection
Diagram Nomenclature

- Composite Repairs Cost Too Much
- Composite Parts Get Damaged
- Composite Repairs Cost 50% Less

- Cause-Effect Arrow
- Or
- Necessary Condition Arrow

- Logical “And”
- Or
- Sufficiency

- Conflict Arrow

- Action, Objective or Injection
Diagram Nomenclature

Sufficiency Based Logic:

If this then that

OR

AND
Too frequently, damaged structural components must be repaired (prior to the next flight). 

High cost of maintenance, inspection and repair of composite structures.

Operators make large investments in composite structural component spares.

Damaged composite structural components often cause A.P. down-time.

A.P. down-time is a cost to the industry.

Composite repair materials are expensive.

Composite Repair labor is expensive.

Too frequently, damaged structural components must be repaired (prior to the next flight).

Lengthy elapsed time required to permanently repair composite structural components.
Composite repair materials are expensive

A significant amount of composite Mat’l must be scrapped due to exceeding shelf life limits

Operators/MROs minimize their stock of a particular composite Mat’l for repairs

Operators/MROs are often out of stock for a particular composite Mat’l for repairs

Composite (repair) mat’ls have a short shelf life

Operators/MROs have to order more composite mat’l than they need for any particular OEM

Demand for any particular composite Mat’l for repair is very small

Mat’l suppliers requires min. batch sizes to cover set-up costs

Composite materials are used to repair damaged composite structural components

Each OEM calls for a unique composite material

There are few repair material industry standards available

Rarely will an OEM’s existing preferred repair Mat’l be SAE qualified

Cost of manufacturing composite materials is inversely proportional to the demand

See Page 1.1

See Page 1.2

See Top Page "Cost of Maintenance"

See Page 5 "Excessive Repair Flow"

See Page 5.2 “Excessive Unique Repair Appr Flow"
Composite (repair) mat’ls have a short shelf life.

Materials that exceed shelf life limits can be re-tested to verify acceptable material properties.

There is a lack of OEM approved material re-test parameters.

Wet layup composite repair materials have a much greater shelf life than pre-preg’s.

There is a lack of OEM approved repairs that call for wet-layup materials.

See Page 1 “Materials Are Expensive”
Composite repair materials are expensive

A significant amount of composite Mat’l must be scrapped due to exceeding shelf life limits

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Composite (repair) mat’ls have a short shelf life

Operators of mixed fleets (& MROs) must stock multiple types of composite Mat’ls for repair

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Composite repair materials are expensive

See Top Page “Cost of Maintenance”

See Page 1.1

See Page 5 “Excessive Repair Flow”

See Page 5.2 “Excessive Unique Repair Appr Flow”
Rarely will an OEM’s existing preferred repair Mat’l be SAE qualified

It is a poor ROI for supplier of existing preferred repair Mat’l to seek SAE Qualification

It costs money to qualify as SAE repair Mat’l

An OEM’s preferred repair Mat’l will see minimal additional demand for being SAE qualification

The OEM’s preferred repair Mat’l is already allowed in the OEM’s SRM

Few OEMs allow the use of SAE repair Materials

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See Page 1.1

See Page 5 “Excessive Repair Flow”

See Page 5.2 “Excessive Unique Repair Appr Flow”

See Page 1.2
Too frequently, damaged structural components must be repaired (prior to the next flight).

High cost of maintenance, inspection and repair of composite structures.

Operators make large investments in composite structural component spares.

Damaged composite structural components often cause A.P. down-time.

Composite repair materials are expensive.

A.P. down-time is a cost to the industry.

Composite Repair labor is expensive.

Operators make large investments in composite structural component spares.

Lengthy elapsed time required to permanently repair composite structural components.

See Page 1
See Page 2
See Page 3
See Page 4
See Page 5
See Page 6
Repair Labor is Expensive

Composites repair labor is expensive

- Too frequently, there is improper repair of composite structural components
- Rework is necessary to correct improper composite structural repair
- Sub-division of a resource pool reduces the effective supply of that resource

Technicians with the necessary specialized skills are expensive

- Labor rates generally follow the principles of supply and demand
- The supply of technicians with the necessary specialized composite repair skills is not meeting industry demand

- Operator/MRO must develop technicians w/special skills
- Knowledge and skill of processes and materials is necessary to accomplish composite repair successfully

- Special composite repair skills development training for technicians is expensive
- Supply of technicians is restricted to those with knowledge of OEM specific processes and materials

- Too frequently, there are false indications of improper repair
- Additional flow time is needed to rework improperly completed composite structural repairs
- Additional labor is needed to rework improperly completed composite structural repairs

See Page 5.1
See Page 2.2
See Page 5
See Page 6
Technicians confuse OEM specific repair processes or materials.

There is no industry standard set of composite repair skills and capabilities for technicians.

Supply of technicians is restricted to those with knowledge of OEM specific processes and materials.

Knowledge and skill of processes and materials is necessary to accomplish composite repair successfully.

See Page 2.2 “Improper Repair”

See Page 2 “Repair Labor is Expensive”

See Page 5.2 “Excessive Unique Repair Appr Flow”

Technicians work on airplanes from different OEMs.
Improper Repair

Too frequently, there is improper repair of composite structural components.

- Use of OEM approved processes and materials is necessary to accomplish composite repair successfully.
- Technicians confuse OEM specific repair processes or materials.
- Additional process controls increase operational costs.
- Repair organizations are not likely to implement process controls beyond that which is specified.
- Repair organizations strive to operate profitably.

Too frequently, approved repair procedures are not followed.

Too frequently, repair procedures lack adequate specificity.

- Too frequently, unpublished repair procedures lack adequate specificity.
- Too frequently, published repair (SRM) procedures lack adequate specificity.

See Page 2
“Repair Labor is Expensive”
Repair Labor is Expensive

Composite repair labor is expensive

There is a need for a large supply of technicians with composite repair skills

Technicians with the necessary specialized skills are expensive

Labor rates generally follow the principles of supply and demand

Operator/MRO must develop technicians with special skills

Special composite repair skills development training for technicians is expensive

The supply of technicians with the necessary specialized composite repair skills is not meeting industry demand

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Sub-division of a resource pool reduces the effective supply of that resource

Too frequently, there are false indications of improper repair

Too frequently, there is improper repair of composite structural components

Rework is necessary to correct improper composite structural repair

Additional flow time is needed to rework improperly completed composite structural repairs

Additional labor is needed to rework improperly completed composite structural repairs

Too frequently, rework is necessary to correct improper composite structural repair

See Top Page “Cost of Maintenance”

See Page 5 “Excessive Repair Flow”

See Page 5.1

See Page 2.2

See Page 2.1

See Page 6
High cost of maintenance, inspection and repair of composite structures

Composite repair materials are expensive
See Page 1

Composite Repair labor is expensive
See Page 2

Operators make large investments in composite structural component spares
See Page 3

Damaged composite structural components often cause A.P. down-time
See Page 4

Too frequently, damaged structural components must be repaired (prior to the next flight)
See Page 6

Lengthy elapsed time required to permanently repair composite structural components
See Page 5

A.P. down-time is a cost to the industry
Operators make large investments in composite structural component spares

Often composite structural components spares are expensive

Operators buy spare components to seed their spares stock

There is a need for a larger supply of spare composite structural components

Some spare composite structural components are no longer manufactured

Stocking levels of composite structural component spares is often low

Too frequently, damaged structural components must be repaired (prior to the next flight)

Lengthy elapsed time required to permanently repair composite structural components

See Top Page
“Cost of Maintenance”

See Page 4
“A/P Downtime”

See Page 6

See Page 5
Damaged composite structural components often cause A.P. down-time

- Too frequently, damaged structural components must be repaired (prior to the next flight)
- Lengthy elapsed time required to permanently repair composite structural components
- Stocking levels of composite structural component spares is often low
- Components that are not stocked in spares take more flow time to obtain
- Spare composite structural components are often needed with little flow time
- On-wing flow time is required to drill and trim spare details
- Some damaged structural components need to be replaced prior to the next flight
- It is difficult to achieve the necessary process controls if repairing “on-wing”
- Often, there is little time for airplane maintenance before the next flight

See Top Page “Cost of Maintenance”

See Page 3
Too frequently, damaged structural components must be repaired (prior to the next flight).

High cost of maintenance, inspection and repair of composite structures

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A.P. down-time is a cost to the industry

Lengthy elapsed time required to permanently repair composite structural components

Operators make large investments in composite structural component spares

Too frequently, damaged structural components must be repaired (prior to the next flight)
Lengthy elapsed time required to permanently repair composite structural components

- Certain realities of composites repair physically require flow time to complete successfully
  - Part preparation requires flow time (e.g., moisture removal)
  - Repair materials preparation requires flow time (e.g., thawing of frozen materials)
  - Repair processes require flow time (e.g., cure cycle)

- Operators/MROs are often out of stock for a particular composite Mat’l for repairs

- Flow time is needed to procure any particular composite mat’l for repairs
- Additional flow time is needed to rework improperly completed composite structural repairs

- Too frequently, repairs are re-inspected

- Often, excessive flow time is required to approve Operator/MRO unique repair designs

- Often operators seek repair options with faster flow times to complete (time limited vs permanent)

See Top Page
“Cost of Maintenance”

See Page 4
“A/P Downtime”

See Page 3
“Large Investment in Spares”

See Page 1

See Page 2

See Page 5.1

See Page 5.2
Too frequently, repairs are re-inspected

Too frequently, there are false indications of improper repair

Too frequently, there are ambiguous indications of improper repair

Too frequently, improper repair is not detected

Too frequently, damage to composite structure is not detected

NDI techniques used to detect improper repair of composite structures vary

There is not clear guidance for selection of the appropriate NDI technique

Ability of NDI to detect damage is dependent on construction details

Composite structures vary in construction (e.g., laminate, h/c sandwich)

See Page 2 “Repair Labor is Expensive”

See Page 5.2.1 “Small Repair Limits”

See Page 5 “Excessive Repair Flow”

See “Another Day”
**CACRC CRT**

**Page 5 – Excessive Repair Flow**

- Lengthy elapsed time required to permanently repair composite structural components
  - Certain realities of composites repair physically require flow time to complete successfully
  - Operators/MROs are often out of stock for a particular composite Mat’l for repairs
  - Flow time is needed to procure any particular composite mat’l for repairs
  - Repair processes require flow time (e.g., cure cycle)
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See Top Page “Cost of Maintenance”

See Page 4 “A/P Downtime”

See Page 3 “Large Investment in Spares”

See Page 1

See Page 2

See Page 5.1

See Page 5.2
There are often small composite bonded repair limits for PSEs

There is no industry standard composite repair analysis approach

There are often small composite bonded repair limits for PSEs

Each OEM has a limited set of standard (published) repairs

Lengthy elapsed time required to permanently repair composite structural components

Operators/MROs are often out of stock for a particular composite repair Mat’l

Good repair design accounts for availability of materials

Good repair design accounts for availability of skills and capabilities

Often operators seek repair options with faster flow times to complete (time limited vs permanent)

Often, Operator/MRO unique repairs require excessive analysis by OEM

Each OEM has a limited repair design, analysis and approval resources

Many requests to OEM’s asking for unique repair’s/or approvals

Often Operator/MROs develop unique repair designs (incl., Mat’l/Process deviations from OEM published repairs)

Often, excessive flow time is required to approve Operator/MRO unique repair designs

There is no industry standard set of composite repair skills and capabilities for technicians

See Page 2

See Page 1

See Page 5

See Page 5.2.2

See Page 5.2.1
There are often small composite bonded repair limits for PSEs.

PSEs must be shown to be failsafe (carry limit load) with the bonded repair failed.

It becomes more & more difficult to show the structure is failsafe as the damage size increases.

Process controls are needed to ensure necessary reliable composite bonded repairs.

Reliance on in process controls is insufficient to ensure safety of flight (policy).

Some composite bonded repairs details can not be reliably verified by practical post-process inspections.

Some composite bonded repair details greatly influence the repair strength & durability.

Too frequently, improper repair is not detected.

See Page 5.2
“Excessive Flow to Approve”

Some composite bonded repair details greatly influence the repair strength & durability.

See Page 5.1

Ply layup & Stacking Sequence

Use of qualified materials & process

Poorly formed adhesion (“weak bonds” or “tight disbonds”)
There are often small composite bonded repair limits for PSEs

Many requests to OEM’s asking for unique repair’s/or approvals

Operators/MROs often seek to repair components beyond published repair limits

Often, excessive flow time is required to approve Operator/MRO unique repair designs

Each OEM has a limited repair design, analysis and approval resources

Often, Operator/MRO unique repairs require excessive analysis by OEM

See Page 5.2.1

There are often small composite bonded repair limits for PSEs

Lengthy elapsed time required to permanently repair composite structural components

See Page 5.2.2

There is no industry standard composite repair analysis approach

See Page 5

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Often, Operator/MRO unique repairs require excessive analysis by OEM

See Page 5
Most OEM’s consider their composite material allowables and analysis approach proprietary (policy).

There is no industry standard composite repair allowables and analysis approach.

Some composite material allowables and analysis approach is export controlled (policy).

Industry standards are available to everyone.

Misapplication of composite allowables and analysis could jeopardize product reliability and safety.

An OEM’s design/process specific composite allowables and analysis could be mis-applied.

Knowledge of an OEM’s design/process specific composite allowables and analysis could enable an OEM’s competition.

Composite material allowables are dependent upon design application and manufacturing processes.

There is not a reliable analysis method to calculate redistribution of internal loads in composite structural components.

See Page 5.2 “Excessive Flow to Approve”
There are often small composite bonded repair limits for PSEs

Many requests to OEM’s asking for unique repair’s/or approvals

Each OEM has a limited repair design, analysis and approval resources

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Lengthy elapsed time required to permanently repair composite structural components

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Good repair design accounts for availability of skills and capabilities

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Lengthy elapsed time required to permanently repair composite structural components

Certain realities of composites repair physically require flow time to complete successfully

Part preparation requires flow time (e.g., moisture removal)

Repair materials preparation requires flow time (e.g., thawing of frozen materials)

Repair processes require flow time (e.g., cure cycle)

Operators/MROs are often out of stock for a particular composite Mat’l for repairs

Flow time is needed to procure any particular composite mat’l for repairs

Additional flow time is needed to rework improperly completed composite structural repairs

Too frequently, repairs are re-inspected

Often, excessive flow time is required to approve Operator/MRO unique repair designs

Often operators seek repair options with faster flow times to complete (time limited vs permanent)

See Page 3

“Large Investment in Spares”

See Page 4

“A/P Downtime”

See Top Page

“Cost of Maintenance”

See Page 1

See Page 5

See Page 2

See Page 5.1

See Page 5.2
Too frequently, damaged structural components must be repaired (prior to the next flight).

High cost of maintenance, inspection and repair of composite structures

Composite repair materials are expensive

Composite Repair labor is expensive

Operators make large investments in composite structural component spares

Damaged composite structural components often cause A.P. down-time

A.P. down-time is a cost to the industry

Lengthy elapsed time required to permanently repair composite structural components

Operators make large investments in composite structural component spares

Composite Repair labor is expensive

Composite repair materials are expensive

Too frequently, damaged structural components must be repaired (prior to the next flight)

See Page 6

See Page 5

See Page 4

See Page 3

See Page 2

See Page 1
Too frequently, damaged structural components must be repaired.

- There are operational and environmental threats to structure.
- Some Composite structural components are not very durable.
- Too frequently, composite structural components are damaged in service.
- Composite structural repair is labor intensive.
- Structural components damaged beyond allowable damage limits must be repaired (prior to the next flight).
- There is a need for a large supply of technicians with composite repair skills.
- Too frequently, composite structural components must be repaired (prior to the next flight).

See Page 2: “Labor is Expensive”
See Page 4: “A/P Downtime” “Large Investment in Spares”
See Page 3: “Cost of Maintenance”
See Page 6.1: Some Composite structural components are not very durable
Some composite structural components are not very durable.

- Some composite structural components have design details that are not durable.
- Some composite structural components designs sacrifice durability to reduce weight.
- Operators want low cost of airframe ownership.
- Operators want airframes with minimal operational costs.
- Operators want durable composite structural components.
- Weight is the airframes’ primary contributor to operational costs.
- Operators want airframes with minimal maintenance costs.
- Operators want light weight composite structural components.
- In most structural composite component designs thinner gauges are less durable.
- Operators want low cost of airframe ownership.
- Durability is the airframes’ primary impact to maintenance costs.

There is limited in-service experience with composite structural components.

It is difficult to determine durability of composite structural components without in-service experience.

Composite structural components are a relatively new design trend.

There are few industry design standards for composite structural components.

Some composite structural components designs increase weight to improve durability.

It is difficult to determine durability of composite structural components without in-service experience.

There is limited in-service experience with composite structural components.

End
The Future Reality Tree

• Helps identify what to change to
• Examines the cause-and-effect logic between change to an existing system and the resulting outcomes
• A logical “test” of the proposed solution
• Verify that a planned solution will, in fact, produce the desired results
• Identify any unfavorable new consequences or negative branch reservations
Future Reality Tree
Construction

- Start with the CRT
- Insert injections from Conflict Resolution Diagram (CRD)
- Formulate Desired Effects (DE)
- Add injections as necessary
- Revise logic as necessary
- Build in positive reinforcing loops
- Add the objective/link to strategy
Some composite structural components are not very durable

Fewer composite structural components have design details that are not durable

There is limited in-service experience with composite structural components

Composite structural components is a relatively new design trend

There are few industry design standards for composite structural components

Weight is the airframes’ primary contributor to operational costs

Operators want airframes with minimal operational costs

Operators want low cost of airframe ownership

In most structural composite component designs thinner gauges are less durable

Operators want durable composite structural components

Operators want airframes with minimal maintenance costs

Durability is the airframes’ primary impact to maintenance costs

Operators want light weight composite structural components

Some composite structural components designs increase weight to improve durability

There is guidance available to the industry to determine durability of composite structural component designs prior to in-service experience

It is difficult to determine durability of composite structural components without in-service experience
Hang In There...We Are Half Way Through
CACRC CRT

Page 6 – Too frequently, damaged structural components must be repaired

Too frequently, composite structural components are damaged in service

There are operational and environmental threats to structure

There are operational and environmental threats to structure

Composite structural repair is labor intensive

Some composite structural components are not very durable

There is a need for a large supply of technicians with composite repair skills

See Page 2 “Labor is Expensive”

See Page 4 “A/P Downtime” “Large Investment in Spares”

See Page 3 “A/P Downtime” “Large Investment in Spares”

“Cost of Maintenance”

See Top Page

“Labor is Expensive”

“Cost of Maintenance”

There is less need for a large supply of technicians with composite repair skills

Less frequently, damaged structural components must be repaired (prior to the next flight)

Less frequently, composite structural components are damaged in service

Structural components damaged beyond allowable damage limits must be repaired (prior to the next flight)

Fewer composite structural components are not very durable

See Page 6.1

See Page 2

See Page 4

See Page 3
High cost of maintenance, inspection and repair of composite structures

Composite repair materials are expensive
See Page 1

Composite Repair labor is expensive
See Page 2

Operators make large investments in composite structural component spares
See Page 3

Damaged composite structural components often cause A.P. down-time
See Page 4

Less frequently, damaged structural components must be repaired (prior to the next flight)
See Page 6

Lengthy elapsed time required to permanently repair composite structural components
See Page 7
Lengthy elapsed time required to permanently repair composite structural components

Certain realities of composites repair physically require flow time to complete successfully

Part preparation requires flow time (e.g., moisture removal)

Repair materials preparation requires flow time (e.g., thawing of frozen materials)

Repair processes require flow time (e.g., cure cycle)

Operators/MROs are often out of stock for a particular composite Mat’l for repairs

Flow time is needed to procure any particular composite mat’l for repairs

Too frequently, repairs are re-inspected

Additional flow time is needed to rework improperly completed composite structural repairs

Often operators seek repair options with faster flow times to complete (time limited vs permanent)

Often, excessive flow time is required to approve Operator/MRO unique repair designs

See Top Page “Cost of Maintenance”

See Page 4 “A/P Downtime”

See Page 3 “Large Investment in Spares”

See Page 5.1

See Page 5.2
Too frequently, the appropriate NDI technique is not used

There is clear guidance for selection of the appropriate NDI technique

Composite structures vary in construction (e.g., laminate, h/c sandwich)

Ability of NDI to detect damage is dependent on construction details

See Page 2
“Repair Labor is Expensive”

Too frequently, damage to composite structure is not detected

See “Another Day”

See Page 5.1 – Frequent Re-inspection

Less frequently, repairs are re-inspected

Ambiguous NDI indications require re-inspection

Less frequently, there are ambiguous indications of improper repair

Less frequently, improper repair is not detected

NDI techniques used to detect improper repair of composite structures varies

Too frequently, there are false indications of improper repair

Too frequently, there are ambiguous indications of improper repair

See Page 5.2.1
“Small Repair Limits”

Less frequently, the appropriate NDI technique is not used

Too frequently, improper repair is not detected

See Page 5
“Excessive Repair Flow”
Composite repair labor is expensive

Technicians with the necessary specialized skills are expensive

Labor rates generally follow the principles of supply and demand

Operator/MRO must develop technicians w/special skills

Special composite repair skills development training for technicians is expensive

The supply of technicians with the necessary specialized composite repair skills is not meeting industry demand

Supply of technicians is restricted to those with knowledge of OEM specific processes and materials

Sub-division of a resource pool reduces the effective supply of that resource

Knowledge and skill of processes and materials is necessary to accomplish composite repair successfully

Too frequently, there is improper repair of composite structural components

Rework is necessary to correct improper composite structural repair

Less frequently, there are false indications of improper repair

See Page 5.1

See Page 2.2

See Page 5

“Excessive Repair Flow”

See Page 6

See Top Page
“Cost of Maintenance”
Technicians confuse OEM specific repair processes or materials less frequently.

There is an industry standard set of composite repair skills and capabilities for technicians.

Supply of technicians is less restricted to those with knowledge of OEM specific processes and materials.

Knowledge and skill of processes and materials is necessary to accomplish composite repair successfully.

See Page 2.2 “Improper Repair”

See Page 2 “Repair Labor is Expensive”

See Page 5.2 “Excessive Unique Repair Appr Flow”
Improper Repair

Too frequently, there is improper repair of composite structural components.

Technicians confuse OEM specific repair processes or materials less frequently.

Use of OEM approved processes and materials is necessary to accomplish composite repair successfully.

Less frequently, approved repair procedures are not followed.

Additional process controls increase operational costs.

Repair organizations are not likely to implement process controls beyond that which is specified.

Repair organizations strive to operate profitably.

There are many industry standard repair procedures which specify appropriate process controls.

Too frequently, unpublished repair procedures lack adequate specificity.

Too frequently, published repair (SRM) procedures lack adequate specificity.

See Page 2.1

See Page 2

“Repair Labor is Expensive”
Repair Labor is Expensive

Composite repair labor is expensive

Too frequently, there is improper repair of composite structural components

Rework is necessary to correct improper composite structural repair

Less frequently, rework is necessary to correct improper composite structural repair

Less flow time is needed to rework improperly completed composite structural repairs

Less labor is needed to rework improperly completed composite structural repairs

Less frequently, there are false indications of improper repair

Rework is necessary to correct improper composite structural repair

Sub-division of a resource pool reduces the effective supply of that resource

Supply of technicians is less restricted to those with knowledge of OEM specific processes and materials

Special composite repair skills development training for technicians is expensive

Labor rates generally follow the principles of supply and demand

The supply of technicians with the necessary specialized composite repair skills is better meeting industry demand

Knowledge and skill of processes and materials is necessary to accomplish composite repair successfully

Technicians with the necessary specialized skills are less expensive

Operator/MRO must develop technicians w/special skills less often

The supply of technicians with the necessary specialized composite repair skills is not meeting industry demand

The supply of technicians is restricted to those with knowledge of OEM specific processes and materials

Technology development is expensive

Technicians with the necessary specialized skills are expensive
Lengthy elapsed time required to permanently repair composite structural components

- Certain realities of composites repair physically require flow time to complete successfully
- Operators/MROs are often out of stock for a particular composite Mat’l for repairs
- Repair materials preparation requires flow time (e.g., thawing of frozen materials)
- Repair processes require flow time (e.g., cure cycle)
- Flow time is needed to procure any particular composite mat’l for repairs
- Less flow time is needed to rework improperly completed composite structural repairs
- Less frequently, repairs are re-inspected
- Often, excessive flow time is required to approve Operator/MRO unique repair designs
- Often operators seek repair options with faster flow times to complete (time limited vs permanent)

- Part preparation requires flow time (e.g., moisture removal)

See Top Page “Cost of Maintenance”
See Page 4 “A/P Downtime”
See Page 3 “Large Investment in Spares”
See Page 1
See Page 2
See Page 5.1
See Page 5.2
Composite repair materials are expensive

Operators/MROs minimize their stock of a particular composite Mat’l for repairs

A significant amount of composite Mat’l must be scrapped due to exceeding shelf life limits

Operators/MROs are often out of stock for a particular composite Mat’l for repairs

Operators/MROs have to order more composite mat’l than they need for any particular OEM

Composite (repair) mat’l’s have a short shelf life

Operators of mixed fleets (& MROs) must stock multiple types of composite Mat’l’s for repair

Demand for any particular composite Mat’l for repair is very small

Mat’l suppliers require min. batch sizes to cover set-up costs

There are few repair material industry standards available

Composite materials are used to repair damaged composite structural components

Each OEM calls for a unique composite material

Rarely will an OEM’s existing preferred repair Mat’l be SAE qualified

Cost of manufacturing composite materials is inversely proportional to the demand

See Top Page “Cost of Maintenance”

See Page 5 “Excessive Repair Flow”

See Page 5.2 “Excessive Unique Repair Appr Flow”

See Page 1.1

See Page 1.2
CACRC CRT
Page 1.2 – Rarely is an OEM’s existing preferred repair Mat’l SAE qualified

Often an OEM’s existing preferred repair Mat’l will be SAE qualified

- It is a good ROI for supplier of existing preferred repair Mat’l to seek SAE Qualification
- Mat’l suppliers seek high ROI

- It costs money to qualify as SAE repair Mat’l
- An OEM’s preferred repair Mat’l will see additional demand for being SAE qualification

- The OEM’s preferred repair Mat’l is already allowed in the OEM’s SRM
- Many OEMs allow the use of SAE repair Materials

See Page 1 “Materials Are Expensive”
Materials are Expensive

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Operators/MROs minimize their stock of a particular composite Mat’l for repairs

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Mat’l suppliers requires min. batch sizes to cover set-up costs

There are many repair material industry standards available

Often an OEM’s existing preferred repair Mat’l be SAE qualified

Operators/MROs minimize their stock of a particular composite Mat’l for repairs

Composite materials are used to repair damaged composite structural components

Fewer OEMs call for unique composite materials

Cost of manufacturing composite materials is inversely proportional to the demand

Demand for any particular composite Mat’l for repair is less small

Composite repair materials are expensive
CACRC CRT
Page 1.1 – Short Shelf Life

Fewer composite (repair) mat’ls have a very short shelf life

Materials that exceed shelf life limits can be re-tested to verify acceptable material properties

There are more OEM approved material re-test parameters

Wet layup composite repair materials have a much greater shelf life than pre-preg’s

There are more OEM approved repairs that call for wet-layup materials

See Page 1 “Materials Are Expensive”
Composite repair materials are less expensive

Operators/MROs minimize their stock of a particular composite Mat’l for repairs

Operators/MROs are rarely out of stock for a particular composite Mat’l for repairs

A smaller amount of composite Mat’l must be scrapped due to exceeding shelf life limits

Operators/MROs may order composite repair mat’l that supports many OEMs

Fewer composite (repair) mat’ls have a very short shelf life

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Composite materials are used to repair damaged composite structural components

Operators/MROs minimize their stock of a particular composite Mat’l for repairs

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See Page 1.1

See Top Page “Cost of Maintenance”

See Page 5.2 “Excessive Unique Repair Appr Flow”

See Page 5 “Excessive Repair Flow”

See Page 1.2
Lengthy elapsed time required to permanently repair composite structural components

- Certain realities of composites repair physically require flow time to complete successfully
- Operators/MROs are rarely out of stock for a particular composite Mat’l for repairs
- Part preparation requires flow time (e.g., moisture removal)
- Repair materials preparation requires flow time (e.g., thawing of frozen materials)
- Repair processes require flow time (e.g., cure cycle)
- Flow time is needed to procure any particular composite mat’l for repairs

Less flow time is needed to rework improperly completed composite structural repairs

- Less frequently, repairs are re-inspected
- Often operators seek repair options with faster flow times to complete (time limited vs permanent)
- Often, excessive flow time is required to approve Operator/MRO unique repair designs

See Top Page “Cost of Maintenance”
See Page 4 “A/P Downtime”
See Page 3 “Large Investment in Spares”
See Page 5.2
See Page 5.1
See Page 2
There are often small composite bonded repair limits for PSEs. Many requests to OEM’s asking for unique repair’s/or approvals. Operators/MROs often seek to repair components beyond published repair limits. Operators/MROs often seek repair options with faster flow times to complete (time limited vs permanent). Often, excessive flow time is required to approve Operator/MRO unique repair designs. Operators/MROs are rarely out of stock for a particular composite Mat’l for repairs. Lengthy elapsed time required to permanently repair composite structural components. There are often small composite bonded repair limits for PSEs. Each OEM has a limited repair design, analysis and approval resources. Often, Operator/MRO unique repairs require excessive analysis by OEM. Each OEM has a limited set of standard (published) repairs. Good repair design accounts for availability of skills and capabilities. Good repair design accounts for availability of materials. There is an industry standard set of composite repair skills and capabilities for technicians. There is no industry standard composite repair analysis approach. There are often small composite bonded repair limits for PSEs.
There are often small composite bonded repair limits for PSEs

PSEs must be shown to be failsafe (carry limit load) with the bonded repair failed

Process controls are needed to ensure necessary reliable composite bonded repairs

Reliance on in process controls is insufficient to ensure safety of flight (policy)

It becomes more & more difficult to show the structure is failsafe as the damage size increases

Some composite bonded repairs details can not be reliably verified by practical post-process inspections

Some composite bonded repair details greatly influence the repair strength & durability

Less frequently, improper repair is not detected

See Page 5.1

See Page 5.2
“Excessive Flow to Approve”

Ply layup & Stacking Sequence

Use of qualified materials & process

Poorly formed adhesion (“weak bonds” or “tight disbonds”)
There are often small composite bonded repair limits for PSEs. Many requests to OEM's asking for unique repair's/or approvals. Operators/MROs often seek to repair components beyond published repair limits. Often, excessive flow time is required to approve Operator/MRO unique repair designs. Operators/MROs often seek repair options with faster flow times to complete (time limited vs permanent). Operators/MROs often seek to repair components beyond published repair limits. Often, Operator/MRO unique repairs require excessive analysis by OEM. Often, excessive flow time is required to approve Operator/MRO unique repair designs. Operators/MROs often seek repair options with faster flow times to complete (time limited vs permanent). Operators/MROs often seek to repair components beyond published repair limits. Often, Operator/MRO unique repairs require excessive analysis by OEM. Often, excessive flow time is required to approve Operator/MRO unique repair designs. Operators/MROs often seek repair options with faster flow times to complete (time limited vs permanent). Operators/MROs often seek to repair components beyond published repair limits. Often, Operator/MRO unique repairs require excessive analysis by OEM. Often, excessive flow time is required to approve Operator/MRO unique repair designs. Operators/MROs often seek repair options with faster flow times to complete (time limited vs permanent). Operators/MROs often seek to repair components beyond published repair limits. Often, Operator/MRO unique repairs require excessive analysis by OEM. There is no industry standard composite repair analysis approach. Each OEM has a limited repair design, analysis and approval resources. Each OEM has a limited set of standard (published) repairs.

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See Page 2

See Page 1

See Page 5

See Page 5.2.1

See Page 5.2.2

See Page 5
Most OEM’s consider their composite material allowables and analysis approach proprietary (policy). There is no industry standard composite repair allowables and analysis approach. Some composite material allowables and analysis approach is export controlled (policy). Industry standards are available to everyone. Misapplication of composite allowables and analysis could jeopardize product reliability and safety. An OEM’s design/process specific composite allowables and analysis could be mis-applied. Composite material allowables are dependent upon design application and manufacturing processes. There is not a reliable analysis methods to calculate redistribution of internal loads in composite structural components. Knowledge of an OEM’s design/process specific composite allowables and analysis could enable an OEM’s competition.
CACRC CRT
Page 5.2 – Excessive flow required to approve unique repairs

- There are often small composite bonded repair limits for PSEs
- There is no industry standard composite repair analysis guidance for reference only
- There is no industry standard set of composite repair skills and capabilities for technicians
- Each OEM has a limited set of standard (published) repairs

Often operators seek repair options with faster flow times to complete (time limited vs permanent)

- Often, Operator/MRO unique repairs require excessive analysis by OEM
- A little less often, Operator/MRO unique repairs require excessive analysis by OEM

Generally, fewer requests to OEM’s asking for unique repair’s/or approvals

- Each OEM has a limited repair design, analysis and approval resources
- Somewhat fewer requests to OEM’s asking for unique repair’s/or approvals

- Operators/MROs often seek to repair components beyond published repair limits
- Operators/MROs often seek to repair components beyond published repair limits

- Good repair design accounts for availability of materials
- Good repair design accounts for availability of materials

- Good repair design accounts for availability of skills and capabilities
- Good repair design accounts for availability of skills and capabilities

- There is an industry standard set of composite repair skills and capabilities for technicians

- Operators/MROs are rarely out of stock for a particular composite Mat'l for repairs

- Lengthy elapsed time required to permanently repair composite structural components

- Each OEM has a limited set of standard (published) repairs

See Page 5
See Page 5.2.1
See Page 1
See Page 2
CACRC CRT
Page 5 – Excessive Repair Flow

- Certain realities of composites repair physically require flow time to complete successfully
  - Part preparation requires flow time (e.g., moisture removal)
  - Repair materials preparation requires flow time (e.g., thawing of frozen materials)
  - Repair processes require flow time (e.g., cure cycle)

- Less elapsed time is required to permanently repair composite structural components
  - Flow time is needed to procure any particular composite mat’l for repairs

- Less frequently operators seek repair options with faster flow times to complete (time limited vs permanent)
  - Less frequently, repairs are re-inspected
  - Less frequently, excessive flow time is required to approve Operator/MRO unique repair designs

- Less frequently, repairs are re-inspected
  - Less flow time is needed to rework improperly completed composite structural repairs

See Top Page
“Cost of Maintenance”

See Page 4
“A/P Downtime”

See Page 3
“Large Investment in Spares”

See Page 1

See Page 2

See Page 5.1

See Page 5.2
High cost of maintenance, inspection and repair of composite structures

Operators make large investments in composite structural component spares

A.P. down-time is a cost to the industry

Composite repair materials are less expensive

Composite Repair labor is less expensive

Damaged composite structural components often cause A.P. down-time

Less frequently, damaged structural components must be repaired (prior to the next flight)

Less elapsed time required to permanently repair composite structural components

See Page 1

See Page 2

See Page 3

See Page 4

See Page 5

See Page 6
Some spare composite structural components are no longer manufactured.

Stocking levels of composite structural component spares is often low.

There is a need for a larger supply of spare composite structural components.

Operators make a little smaller investments in composite structural component spares.

Operators buy spare components to seed their spares stock.

Often composite structural components spares are expensive.

Some spare composite structural components are no longer manufactured.

There is less need for a large supply of spare composite structural components.

Less frequently, damaged structural components must be repaired (prior to the next flight).

Less elapsed time required to permanently repair composite structural components.

Operators make large investments in composite structural component spares.

See Top Page
“Cost of Maintenance”

See Page 4
“A/P Downtime”

See Page 5
See Page 6
Damaged composite structural components often cause A.P. downtime. Stocking levels of composite structural component spares is often low. Components that are not stocked in spares take more flow time to obtain. On-wing flow time is required to drill and trim spare details. Components that are not stocked in spares take more flow time to obtain. Rarely is trimming & drilling to install spare composite structural details. Operators make a little smaller investments in composite structural component spares. It is difficult to achieve the necessary process controls if repairing “on-wing.” It is difficult to achieve the necessary process controls if repairing “on-wing.” Fewer damaged structural components need to be replaced prior to the next flight. Fewer damaged structural components need to be replaced prior to the next flight. It is difficult to achieve the necessary process controls if repairing “on-wing.” It is difficult to achieve the necessary process controls if repairing “on-wing.”
High cost of maintenance, inspection and repair of composite structures

Too frequently, damaged structural components must be repaired (prior to the next flight)

Operators make large investments in composite structural component spares

Damaged composite structural components often cause A.P. downtime

A.P. downtime is a cost to the industry

Reduced cost of ownership, while enhancing safety

Some composite structural components designs increase weight to improve durability

Too frequently, damage to composite structure is not detected

Composite repair materials are less expensive

Composite Repair labor is less expensive

Operators make a little smaller investment in composite structural component spares

Damage composite structural components cause less AP downtime

Less frequently, damaged structural components must be repaired (prior to the next flight)

Less elapsed time required to permanently repair composite structural components

Lower cost of maintenance, inspection and repair of composite structures

Composite repair materials are less expensive

Composite Repair labor is less expensive

Operators make a little smaller investment in composite structural component spares

See Page 1

See Page 2

See Page 3

See Page 4

See Page 5

See Page 6
Too frequently, the appropriate NDI technique is not used

Ambiguous NDI indications require re-inspection

Less frequently, there are false indications of improper repair

See Page 2  
“Repair Labor is Expensive”

See Page 5  
“Excessive Repair Flow”

Less frequently, there are ambiguous indications of improper repair

Less frequently, improper repair is not detected

Less frequently, repairs are re-inspected

See Page 5.2.1  
“How Small Repair Limits”

NDI techniques used to detect improper repair of composite structures vary

There is clear guidance for selection of the appropriate NDI technique

Ability of NDI to detect damage is dependent on construction details

Composite structures vary in construction (e.g., laminate, h/c sandwich)

Too frequently, damage to composite structure is not detected

See "Another Day"
Too frequently, the appropriate NDI technique is not used

Too frequently, damage to composite structure is not detected

Composite structure is designed to meet requirements with non-visible damage (Policy)

High probability that composite structure is safe even if damage is not detected

There is a possibility that technicians do not inspect damaged areas of composite structure

It is difficult to know where to inspect for damage to composite structure

Damage to composite structure may not be visible

Less frequently, the appropriate NDI technique is not used
High cost of maintenance, inspection and repair of composite structures

Too frequently, damaged structural components must be repaired (prior to the next flight)

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Less elapsed time required to permanently repair composite structural components

Lower cost of maintenance, inspection and repair of composite structures

See Page 1

See Page 2

See Page 3

See Page 4

See Page 5

See Page 6
Some composite structural components are not very durable

- Some composite structural components have design details that are not durable
  - It is difficult to determine durability of composite structural components without in-service experience
  - There is limited in-service experience with composite structural components
    - Composite structural components is a relatively new design trend
  - There are few industry design standards for composite structural components

- Some composite structural components designs sacrifice durability to reduce weight
  - Weight is the airframes’ primary contributor to operational costs
    - Operators want light weight composite structural components
    - Operators want airframes with minimal operational costs
  - Operators want airframes with minimal maintenance costs
    - Operators want durable composite structural components
    - Durability is the airframes’ primary impact to maintenance costs
  - Operators want low cost of airframe ownership
  - Operators want durable composite structural components designs increase weight to improve durability

Some composite structural components designs increase weight to improve durability

- Some composite structural components designs increase weight to improve durability
  - Operators want low cost of airframe ownership
  - Operators want durable composite structural components
    - Operators want airframes with minimal maintenance costs
  - Operators want airframes with minimal operational costs
    - Weight is the airframes’ primary contributor to operational costs
  - Operators want light weight composite structural components
    - It is difficult to determine durability of composite structural components without in-service experience
    - There is limited in-service experience with composite structural components
      - Composite structural components is a relatively new design trend
  - There are few industry design standards for composite structural components
Summary of Injections

- There is guidance available to the industry to determine durability of composite structural component designs prior to entering service.
- There is clear guidance for selection of the appropriate NDI technique.
- Many OEMs allow the use of SAE repair Materials.
- There are more OEM approved material re-test parameters.
- There is industry standard composite repair analysis guidance for reference only.
- There are many industry standard repair procedures which specify appropriate process controls.
- There is an industry standard set of composite repair skills and capabilities for technicians.
- There is clear guidance for selection of the appropriate NDI technique.
- Many OEMs allow the use of SAE repair Materials.
- There are more OEM approved repairs that call for wet-layup materials.
CACRC Task Groups

**Design**
- Developed design guide for repairable supportable composite structures (inactive)

**Analysis**
- Develop a standard repair design and analysis document, guidance only

**Materials**
- Develop repair material specifications in support of commercial airplane bonder repairs

**Techniques**
- Develop standard repair process documents from current best practices, does not conduct research

**Inspection**
- Develop Composite NDT calibration standards, and conducts inspection detection round robins in conjunction with Sandia national labs

**Training**
- Develop standard curricula for non NDT inspectors, technicians and engineers

**Procedures**
- Develop documents that provide key characteristics for the overhaul of production components

**Executive**
- TBD
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Repair Terminology

- Design
- Material
- Procedure
- Technique
Example Repair Procedure

- Clean part per ARP4916
- Remove damaged material and taper sand per AIR5367
- Fabricate (X) plies using AMS2980 Dry Fabric
- For each repair ply No.1 to n, impregnate, cut and layup at XX° orientation to repair area per ARP5319 using AMS2980 resin
- Vacuum bag repair per ARP5143
- Apply heat and cure repair laminate per ARP5144
- Perform NDI of repair per ARP5605

Repair Technique

Repair Material
Allowables & Analysis Standards

- CMH-17 has (and is) addressing the two major policy issues preventing further progress by the CACRC
  - Proprietary concerns
  - Export controls
- CACRC could benefit from collaboration with CMH-17
  - Reaps allowables and analysis benefits with minimal CACRC effort
  - CACRC focus on elements of our problems that are not being addressed in the industry
- Does NOT mean CACRC abandons efforts
  - CACRC needs to sponsor repair design and analysis aspects with CMH-17
Recommendations
Executive Committee – Page 1

• Reach agreement on the scope of the system
  – What problems really are for “another day”?  
• Reach agreement on the direction of the solution
  – Finite list of injections 
• Align task groups to the direction of the solution
  – “Airworthiness” re-chartered to “Procedures”
  – “Analysis” re-chartered to work through the CMH-17
Recommendations
Executive Committee – Page 2

• Reword the CACRC Bylaws (slightly)…
  – Problem:
    • Was: Cost of ownership of composite aircraft and engines structures has become a serious concern.”
    • To be: High maintenance, inspection and repair cost of composite aircraft and engines structures
  – Charter:
    • Was: To reduce maintenance, inspection and repair cost, while enhancing safety.”
    • To Be: Lower the cost of ownership of composite aircraft and engines structures while enhancing safety.
Summary

• The CACRC is chartered to solve some significant industry problems
• These problems are systemic in nature and not any “one’s fault”
• Understanding the system is the first step in solving our problems
• Agreeing on the direction of the solution is next
• Working together we can significantly improve the future for the industry
Special Thanks
Interviews with industry experts

• Eric Chesmar, United Airlines, Component Tech Services
• Tim Harris, Boeing, Training & Flight Services Structures Maintenance Training
• Todd Herrington, Delta Airlines, Delta Technical Operations – Composite Structures
• Larry Ilcewicz, Federal Aviation Administration, Chief Scientific & Technical Advisor for Advanced Composite Materials
• Arne Lewis, Boeing, Service Engineering
• Jan Popp, Lufthansa Technik AG, Product Engineering & Planning - Airframe Related Component Services
• Stephen Johnson – Chief Engineer, Boeing (Retired)
References

• "ATA/IATA/SAE Commercial Aircraft Composite Repair Committee (CACRC)," Letter, Todd M. Herrington of Delta TechOps, et. al. to Dr. Chris Markou, Assistant Director Engineering and Environmental Operations, International Air Transport Association, dated February 23, 2011.


• “Commercial Aircraft Composite Repair Committee (CACRC) Bylaws, Revision 1” Date Approved January 12, 2012
  http://www.sae.org/servlets/works/committeeResources.do?resourceID=254302